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THE FEASIBILITY OF CRISIS RELOCATION IN THE NORTHEAST CORRIDOR.(U)
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1 OF 3
AD A038274

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STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

STANFORD RESEARCH INSTITUTE
SRI-Washington D.C. Office · U.S.A.

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THE FEASIBILITY OF CRISIS RELOCATION IN THE NORTHEAST CORRIDOR

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Prepared for:
DEFENSE CIVIL PREPAREDNESS AGENCY
WASHINGTON, D.C. 20301

CONTRACT DCPA01–75–C–0280
DCPA Work Unit B2313B

SRI Project EGU–4243

DCPA REVIEW NOTICE

This report has been reviewed in the Defense Civil Preparedness Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Defense Civil Preparedness Agency.

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Main Office and Laboratories: Menlo Park, California 94025, U.S.A.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

6 THE FEASIBILITY OF CRISIS RELOCATION IN THE NORTHEAST CORRIDOR.

5. TYPE OF REPORT & PERIOD COVERED

9 FINAL rept.,

6. PERFORMING ORG. REPORT NUMBER

~~CRESS~~-20

7. AUTHOR(s)

10 Walmer E./Strope, Clark D./Henderson, Charles T./Rainey

8. CONTRACT OR GRANT NUMBER(s)

15 DCPA01-75-C-0280 new

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, California 94025

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

DCPA Work Unit B2313B

11. CONTROLLING OFFICE NAME AND ADDRESS

Defense Civil Preparedness Agency
Washington, D.C. 20301

12. REPORT DATE

11 Dec[redacted]76

13. NO. OF PAGES

244

14. MONITORING AGENCY NAME & ADDRESS (if diff. from Controlling Office)

15. SECURITY CLASS. (of this report)

Unclassified

12 238p.

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

N/A

16. DISTRIBUTION STATEMENT (of this report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

CIVIL DEFENSE
STRATEGIC EVACUATION
FEASIBILITY STUDY

332 500
JB

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The feasibility of relocation of 47 million persons over a three-day period from areas at potential risk in event of nuclear attack in the densely-populated Northeast and Middle Atlantic regions was examined to determine whether travel distances to host areas were reasonable, transportation capacities were sufficient, and whether fallout protection could be provided. It was found that congregate-care housing at 20 square feet per person could be provided at an average travel distance of 100 miles. Transportation contraints in the vicinity of the very large cities would require that limited-access highways be made one-way outbound. (cont.)

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EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. KEY WORDS (Continued)

20 ABSTRACT (Continued)

cont

New York City was identified for special study. High-quality fallout protection (expedient shelter construction) would be required in much of the study area.

DD FORM 1 JAN 73 1473 (BACK)

EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

CRESS-20
Project EGU-4243

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for

Defense Civil Preparedness Agency
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THE FEASIBILITY OF CRISIS RELOCATION IN THE NORTHEAST CORRIDOR

SUMMARY

The area dominated by urbanization stretching from Boston in the north to Washington in the south, the so-called Northeast Corridor, offers a major problem in crisis relocation planning. The 14-State area comprising DCPA Regions 1 and 2, which contain the Northeast Corridor and its outlying risk areas and hosting space, had a 1970 census population of 60.4 million, 30 percent of the U.S. population. According to the DCPA risk criteria, nearly 47 million of these people are considered at blast risk and 1.7 million at fallout risk. Less than 12 million reside in areas that could be used for hosting relocatees from the blast-risk zones.

Three questions of feasibility were examined in the study area:

- Whether a suitable allocation of risk-area residents to available host capacities could be made that would avoid unreasonably large relocation distances, permit commuting of essential workers to key risk-area facilities, and allow hosting to be based on nonresidential facilities in the host communities.
- Whether highway capacities would permit the exodus to be completed in a three-day period and whether other modes of transport would be sufficient for those without automobiles.
- Whether the fallout conditions postulated by the risk assumptions would require higher-than-average protection criteria and whether the means of providing such protection are available.

It was determined that hosting of the risk populations could be based on congregate-care facilities if the peacetime emergency housing allotment of 40 square feet per person is reduced to 20 square feet. The average

relocation distance at the reduced housing space allotment would be about 100 miles and the maximum travel distance for any relocatee would be not more than 288 miles. To minimize travel distance, relocatees are not assigned to West Virginia and there is much unused hosting space in southern Virginia, northern Maine and western New York State. Use of these more remote locations by airlift would seem feasible.

Commuting of essential workers appears to be feasible if their numbers are restricted to less than 8 percent of the population. The average commuting distance was found to be 42 miles; the maximum, 80 miles.

The capacity of the highway system in the vicinity of the very large cities determines the time scale of a crisis relocation in the Northeast Corridor. It does not appear possible to empty the large cities (Boston, New York, Philadelphia, Baltimore, and Washington) in a period of three days unless limited-access highways are made one-way outbound. Even so, over four days would be required to evacuate New York City. The assumption of surface bursts for fallout risk is the most sensitive criterion for general feasibility. For example, if the parts of New Jersey not at blast risk were available for hosting, it appears that New York City could be emptied in three days.

Maximum use of nonhighway modes of transport will be necessary in the large cities. While such use appears feasible, more study of the operational aspects is needed. A detailed analysis of the transportation aspect is underway in New York City.

Under the all-surface-burst assumption, high-quality fallout protection (PF greater than 40) will be required in a large part of the study area. Construction of expedient shelters will need emphasis rather than the upgrading of existing buildings.

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I INTRODUCTION

Background

A national crisis relocation policy as one option for reducing the vulnerability of the population of the United States to the threat of nuclear attack is under active development and prototype testing by the Defense Civil Preparedness Agency. At least part of the justification for this development is the fact that crisis evacuation has emerged as a basic civil defense option in the Soviet Union.[1] Plans for evacuation of U.S. cities in response to evacuation of Soviet cities in a crisis may be regarded as a stabilizing influence contributing to crisis resolution. It is also a measure that has the potential of saving tens of millions of lives, should the crisis escalate to nuclear war.

A major planning problem for the United States is believed to be the relocation in a crisis of the population at risk in the heavily urbanized northeastern part of the country. Many responsible civil defense professionals are dubious of the practicability of several key aspects of crisis relocation in the area dominated by urbanization stretching from Boston on the north to Washington in the south, the so-called Northeast Corridor. For one thing, a relocation movement that would match the pace attributed to Soviet capabilities would need to be accomplished within a period of three days. Just how many people could physically leave cities such as New York, Boston, and Philadelphia during a three-day period, considering the capacity of existing highways and the fact that half or more of the central city residents do not possess automobiles? How far would these urbanites have to go to find some kind of temporary lodging?

Other questions have to do with the means by which food and other necessities of life would be provided to the relocated population and their hosts. If producers and distribution centers in the risk areas are to remain in operation for this purpose, is it feasible for essential workers to commute to and from the nearest host areas? And, finally, what about fallout protection, should the crisis escalate to attack rather than being resolved? There is inadequate high-quality fallout shelter space in nonmetropolitan areas for the people who live there, let alone space for relocated urban residents.

As part of an effort to obtain answers to these questions of feasibility, the Defense Civil Preparedness Agency contracted with the Stanford Research Institute to conduct a study of the following scope:

1. Analyze the problems of crisis relocation of risk-area populations in and within the States comprising DCPA Regions I and II.

2. Evaluate tradeoffs, and mixed options or alternatives, including but not limited to:

   a. giving priority for hosting capacity to the largest cities

   b. sheltering critical employees in place or (for example) at mass transit terminals

   c. using small urbanized areas as distribution centers

   d. developing stocks of critical supplies.

To accomplish this analysis, Stanford Research Institute assigned experienced members of its professional staff and entered into a subcontract for a portion of the work with the Center for Planning and Research, Inc. Mr. Charles T. Rainey of CPR, Inc. is a co-author of this report.

The scope of work cited above constitutes Phase I of the contract effort. Two more phases were added by amendment. Phase II concerns the

application of the results of the feasibility study through the preparation of guidance for planners so that they could carry out crisis relocation planning for large cities and areas of high population density, not only in the Northeast Corridor but elsewhere as well. Phase III was a field test of the planning guidance.

Purpose

The purpose of this report is to present the essential results and conclusions concerning the feasibility of crisis relocation in the Northeast Corridor and to describe the Phase II planning guidance and the results of field testing. The draft planning guidance has been submitted to DCPA separately.

Organization of the Report

There are seven sections to this report, including this introduction. Section II describes and documents the initial feasibility analysis, together with intermediate results. The next section discusses what appear to be the critical aspects of the general feasibility analysis and exhibits the sensitivity of the results to the main assumptions and inputs. Conclusions are drawn as to desirable modifications and adjustments that would improve the feasibility estimates without doing violence to current policies and guidance. These adjustments are reflected in Section IV, where our "best" solution to the problems of crisis relocation in the Northeast Corridor is presented. Details related to this solution are contained in two appendices. More radical solutions to the remaining problems are discussed in Section V in the form of alternative policies and their consequences. Section VI describes the planning guidance and the testing of this guidance. Section VII presents our conclusions and recommendations.

II FEASIBILITY ANALYSIS

General

This section describes the general analysis of the feasibility of crisis relocation in the Northeast Corridor of the United States. Additional calculations and adaptations evoked by the nature of the results are presented as part of the evaluation of feasibility in the following section. In accordance with the scope of work, the study area was taken to include the 14-state area comprising DCPA Regions 1 and 2. A listing of these States, together with the risk information from the computer printout provided by DCPA as an input to the analysis, is given in Table 1.

The three major questions of feasibility that were apparent prior to the analysis and to which most of the study effort was devoted are:

- Whether a suitable allocation of risk-area residents to available host capacities could be made that would avoid unreasonably large relocation distances, permit commuting of essential workers to key risk-area facilities, and allow hosting to be based on nonresidential facilities in the host communities.
- Whether highway capacities would permit the exodus to be completed in a reasonable time under feasible traffic controls and whether other means of transportation would be sufficient to accommodate those risk-area residents not having access to a private vehicle.
- Whether the fallout conditions postulated by the risk assumptions would require higher-than-average protection criteria and whether the means for providing such protection are likely to be available.

A brief review of the initial situation in each of these areas of study follows.

Table 1

RISK AND HOST POPULATIONS IN THE STUDY AREA

State	Population	Blast Risk	Fallout Risk	Host Population
DCPA Region 1				
Connecticut	3,032,217	2,710,652	235,725	85,840
Maine	992,048	329,494	-	662,529
Massachusetts	5,689,077	5,199,509	237,888	251,680
New Hampshire	737,681	319,957	81,195	336,529
New Jersey	7,030,306	6,490,144	395,019	145,143
New York	18,177,475	14,868,035	107,602	3,201,838
Rhode Island	949,723	912,276	37,447	none
Vermont	444,732	83,093	-	361,639
DCPA Region 2				
Delaware	547,962	425,530	42,076	80,356
District of Columbia	756,510	756,510	-	none
Maryland	3,918,471	3,344,361	274,089	300,021
Pennsylvania	11,774,961	8,136,736	289,040	3,349,185
Virginia	4,644,384	2,799,638	-	1,844,746
West Virginia	1,744,101	505,961	-	1,238,140
Study Area Totals	60,439,648	46,881,896	1,700,081	11,857,671

Allocation Experience

The previous allocation experience consists of the Operation Survival Plans (OSPs) for tactical evacuation of probable target areas produced in the mid-1950s, and a single run of a computerized allocation procedure for the nine States above the Mason-Dixon line--all of DCPA Region 1 plus Pennsylvania. Since the tactical evacuation plans had been more or less forgotten or were considered irrelevant, much of the doubt and worry about the feasibility of crisis relocation in the Northeast Corridor was brought about by the nature of the results of the computer allocation. Most of this discussion will therefore relate to the more recent computer results.

The principal author of this report conducted a review of the OSPs available at DCPA Region 1 headquarters on August 6, 1975. The Massachusetts and New Jersey plans were of considerable interest as well as several special study reports. These plans involved relocation of 70 percent or more of the risk population, although estimates in various parts of the plans are in disagreement. The total population of Massachusetts in the 1950s was stated to be about 5 million (compared to 5.7 million in the 1970 census), of which about 3.5 million were slated for evacuation. About 1.4 million would go to reception centers in Maine, New Hampshire, and Vermont and about 200,000 people from Connecticut and Rhode Island would be hosted in Massachusetts. There would be about three evacuees per host. Whether any of the potential hosting areas would be at fallout risk in event of attack was not considered in the plan. Thus, in New Jersey, not only would the State's risk population be hosted but also 4.5 million people from New York City and 2 million from Philadelphia. In the current risk assumptions, nearly all of New Jersey is at fallout risk and not available for hosting. In general, evacuees were to be housed in private residences, apparently a family (3-6 persons) per room. The current DCPA assumption is that relocatees will be housed only in nonresidential, nonfarm structures.

The more recent allocation experience is based on a computer program called ADAGIO, which was developed by the Institute for Defense Analyses for DCPA. The program uses a multiplier on the resident population of a host county as a measure of hosting capacity and, within a limit placed on this multiplier by the user, minimizes the average airline relocation distance (not highway distance) required to be traveled by the risk-area residents to their assigned hosting areas. Each host county is partitioned into two hypothetical parts: a rural part and an urban part (small towns and cities). One important restriction on the allocation is that relocatees from only one risk area can be assigned to a given county part. If the assignment does not fully utilize the assumed hosting capacity, it is unavailable for other assignment. Thus, people from two different risk areas can be assigned to a given host county--one to the urban part and one to the rural part--and in both cases there may be unused hosting capacity not available for further allocation.

The application of the ADAGIO program to the nine-State Northeast Corridor gave highly unsatisfactory results and created a general impression of infeasibility of crisis relocation in the area. The single computer run attempted to allocate only 80 percent of the risk population and succeeded in allocating only 73 percent under the ground rules summarized above. Only about 65 percent of the New York City-Northeast New Jersey megalopolis was assigned hosting space, and several smaller risk areas could not be provided hosting space at all. Although an overall average travel distance of 131 miles was achieved, the computer program had no procedure for equalizing the average and maximum travel distances for the various risk areas. Great variations occurred, generally at the expense of the large cities. DCPA Region 1 has noted that the average relocation distance for residents of Springfield-Chicopee-Holyoke, Massachusetts, was about 30 miles, whereas the average relocation distance for residents of Boston was approximately 270 miles. These are, of course, straight-line distances, not highway mileage. Some residents of New York City were assigned to Chautauqua County, New York, a distance

by highway of roughly 400 miles. Results of this type have been considered impractical. A third difficulty encountered was that smaller urban areas tended to relocate to nearby host counties, forcing the major cities to go considerable distances before finding available hosting space for even some of their residents. Use of straight-line distances without other constraints allowed Waterbury and Stamford, Connecticut, for example, to take over Dutchess County, New York, thus forcing all but a few New York City residents to go further. This type of result threw into question the feasibility of maintaining essential functions in the large risk areas by means of the commuting of key workers. A Region 1 analysis concluded that, according to the computer allocation, key workers for Boston would need to commute 80 to 150 miles one way (straight-line). This was found unacceptable and doubt was raised as to whether a major reallocation would insure reasonable travel distances for key workers.

Transportation Adequacy

Reservations about the feasibility of population movement and transportation adequacy, particularly in the large metropolitan areas, have been less sharply defined, since the ADAGIO allocation printout did not take into account movement routes or any other aspects of either the initial relocation movement or the commuting of essential workers. Allegations of nonfeasibility by Region, State, and local civil defense personnel have been based most often on "gut feelings" related to problems of daily normal traffic congestion and movement problems in local disasters. Occasionally, reference has been made to the OSPs of the late 1950s, with the conclusion that the movements proposed probably wouldn't work. Some concern has also been expressed about the ability to transport the high proportion of big-city residents that have no automobiles. Those professionals who have reviewed other past analyses, such as the Hudson Institute study,[2] have noted the discussion of one-week and two-week evacuations whereas the pace of crisis relocation is to be geared to a three-day period as discussed in Section I.

Fallout Protection

Discussions of crisis relocation in the northeastern part of the United States have usually raised issues regarding the availability of fallout shelter in host areas for both residents and relocatees. One issue is phrased as the wisdom of moving people from urban fallout protection to rural areas of deficient fallout protection. Another concerns the multiple surface detonations assumed in the DCPA risk documents and the consequent high dose levels predicted throughout much of the area. Existing shelter in host areas is judged to be poor and the upgrading of existing structures to high PF levels is doubted. The practicability of expedient shelter construction is assessed to be a difficult job. A final issue has to do with the question of how to recognize varying degrees of fallout risk in the utilization of potential hosting areas. In the ADAGIO computer allocation discussed above, people subject to a 50-50 probability of an unprotected effective dose of 10,000 R or more were included in the risk population to be relocated. People in areas with less than the above fallout risk were assumed to be residents of potential host areas. This procedure was criticized on two counts: (1) areas with a 50-50 chance of experiencing 9,500 R were seen as having very little difference in risk from those over 10,000 R, and (2) fallout risk communities were often relocated to nearby areas where the risk was nearly as great—for the wind patterns assumed.

Initial Assumptions

A set of six basic assumptions were made at the beginning of the feasibility analysis. These assumptions could also be considered as the basic criteria for assessing the feasibility of crisis relocation in the Northeast Corridor. If all were found to be satisfied during the analysis, feasibility would be clearly established. On the other hand, modifications of these assumptions might be found necessary. In this case (which is what occurred), alternative assumptions would be explored

that promised a feasible solution. These alternative assumptions are discussed in Section III. The initial assumptions are discussed below.

1. <u>Relocation will be planned for 100 percent of the blast-risk population of Regions 1 and 2, as defined by the computer printout provided by DCPA and summarized in Table 1.</u> This assumption was considered to be the most appropriate for testing the feasibility of relocation in the densely populated Northeast. It will be recalled that the ADAGIO printout discussed earlier aimed at relocating only 80 percent of the risk population and fell short of this goal. The 80-percent figure was one chosen initially by DCPA in recognition that some substantial fraction of the risk population is likely to refuse to relocate even if ordered to do so. A second consideration was that another part of the risk population might well relocate on their own in advance of a directive from the President. Finally, there would always be some segment of the population that would be too ill, infirm, or incorrigible to be relocated from the facilities in which they were patients or inmates. Thus, it was judged that only a number well short of 100 percent would require planned accommodations and would constitute the demand on transportation resources. Our view has been that hosting capacity for everyone who might need it should be available even if it is almost certain that, in the actual event, not all of the capacity will be used. And, we feel that movement of all the risk population constitutes the best assumption for testing the adequacy of transportation resources.

2. <u>The fallout-risk population will not be relocated; however, no blast-risk relocatees will be assigned to such areas</u>. It will be noted from Table 1 that the numbers of people at fallout risk--residents of areas not at blast risk but having a 50-50 chance of experiencing at least 10,000 R unprotected effective dose--amount to less than 2 million, less than 4 percent of those at blast risk. Hence, inclusion of these people in the risk population to be relocated could hardly have a decisive effect on the feasibility of crisis relocation. More careful

examination of where the fallout-risk population is located indicates that only in Connecticut, Massachusetts, and New Jersey would the physical process of relocation be made significantly more difficult. Nonetheless, the relocation of people at fallout risk, by whatever definition is chosen, does not appear to be good planning. First, the actual fallout situation will depend on the winds at the time of attack, not on the statistical winds used in a risk analysis. Unless the fallout-risk population is selectively assigned to host areas at a very much different level of risk—say, upwind (to the west) of assumed detonations—the relocation will not have changed their risk status very much. Similarly, blast-risk people hosted in neighboring jurisdictions that just fail to meet the fallout-risk criterion are often in nearly the same jeopardy as those assessed to be at fallout risk. Only the specific conditions of the attack will determine which is actually at greater risk. Second, and most important, planning to relocate those at fallout risk is tantamount to ignoring the need for good fallout shelters. After all, crisis relocation is an option that may not be executed prior to an attack. Nonetheless, the risk used to plan relocation remains as the risk to be countered in the in-place civil defense plan. If an adequate shelter posture is developed for the in-place contingency, then it seems unnecessary and unwise to plan for a relocation contingency in which the population is uprooted and transplanted to an area of lesser risk but perhaps lesser shelter resources for an influx of relocatees.

At the same time, it is recognized that high-quality shelters will be needed in fallout-risk areas to provide an "adequate" shelter posture. Developing an adequate shelter posture in fallout-risk areas will be a challenging job and should not be made more difficult by the assignment of blast-risk relocatees to these areas. Therefore, one of our initial assumptions was that areas designated to be at fallout risk according to DCPA risk calculations[3,4] will not be involved in crisis relocation, neither as risk population nor as host population.

3. <u>The relocated population will be housed in nonresidential, nonfarm congregate-care facilities in the host counties</u>. DCPA policy in its prototype CRP planning has been to develop a base plan in which all relocatees are assigned housing space in nonresidential, nonfarm structures. Host area surveys have been instituted to locate and measure such space as well as to evaluate the fallout shelter potential in host jurisdictions. It is planned to appeal to host-area residents to take in relocating families at or near the time of a crisis relocation, but the base plan is not to presume that residences will be used. This is in contradistinction to the OSPs of the 1950s in which residential housing at as high as a family per room was assumed. In densely populated areas, such as the Northeast, this assumption means that the feasibility of hosting, in terms of hosting capacity, must be judged in reference to the space identified in host area surveys conducted to date. In view of the allocation experience cited above, full utilization of hosting capacity will be necessary if 100 percent of the blast-risk population is to be housed within reasonable travel distances. To do this, the arbitrary restriction of the ADAGIO computer program in which a given host county is allowed to host relocatees from only one risk area, was considered invalid. As a consequence of this restriction, over 12 million potential hosting spaces were unassigned even though less than 75 percent of the risk population was allocated. It can be seen from Table 1 that, at a hosting ratio of 5 (five relocatees for each host resident), there would be nearly 60 million potential spaces for a blast-risk population of about 47 million. Thus, if a hosting ratio of this magnitude is judged feasible from survey results, there should be more than sufficient housing. Either a lower hosting ratio could be considered or the most remote hosting areas would not be needed.

4. <u>Households possessing one or more automobiles will use the most suitable for relocating</u>. This assumption appears to be in accord with likely human behavior. That is, families possessing an automobile will prefer to use it rather than depend on some other mode of

transportation, especially since emergency advice at the time will urge relocatees to take clothes, medicines, food, bedding, and other essentials with them. Also, families possessing more than one automobile will tend--and may be advised--to use the largest and most reliable one.

In the Northeast Corridor, over two-thirds of the blast-risk population would relocate by private automobile, according to this assumption, making the highway system the most likely stress point in the transportation analysis. The character of the highway system in the Northeast should be given primary consideration in allocation planning. (The computer allocation program has no capability for considering other than the straight-line distance between points defined by geographical coordinates.) As a corollary to this assumption, our feasibility analysis assumes that automobiles are loaded by the average household size in the various risk areas and not to capacity. Other automobiles in those households with more than one will be assumed to be unused.

5. <u>The goal for the movement phase will be to relocate the blast-risk population within a three-day period</u>. As discussed in Section I, the desired movement time is based on estimates of the likely pace of relocation in the Soviet Union. This assumption provides a major test of the feasibility of relocation from the very large cities. Obviously, New York City can be evacuated if no time limits are placed on the operation.

6. <u>Requirements for continued support of the relocated population and for national defense purposes will be met by the commuting of essential workers from nearby host counties</u>. To test the feasibility of a commuting work force, it was assumed that both workers and their families must be hosted together. It was further assumed that workers and their families constituted 20 percent of the risk population. Thus, commuting distances were estimated based on the location of the nearest 20 percent of the relocated population for each risk county. To test

the adequacy of highways and other transportation modes, it was further assumed that 8 percent of the population (from among the close-in 20 percent) were key workers who would need to commute. Where highway capacities were taxed, these persons were assumed to work in two shifts. The numerical assumptions on the size of the essential work force were based on a review of the estimates made by DCPA staffs in the prototype CRP studies.

All ancillary assumptions found necessary during the feasibility analysis were made to be consistent with the foregoing initial assumptions.

No Computer Allocation

A proposition put forward in the SRI proposal for research on the Northeast Corridor Study was that the numbers of people and localities involved in DCPA Regions 1 and 2 made the initial allocation of risk-area residents to appropriate host jurisdictions by computerized calculation almost essential compared to manual assessment. It was proposed to adapt the existing computer code program ADAGIO to correct the major deficiencies previously discussed; namely, to equalize travel distances among risk areas, to fully utilize available hosting space, and to take into account to the extent feasible the existing highway network in making an allocation. It was anticipated that even if successful some manual revision of the output would be necessary to achieve a balanced and feasible allocation. Accordingly, a copy of the ADAGIO source deck was obtained from the Institute for Defense Analyses with the concurrence of DCPA. Received in the latter part of May 1975, the source deck was compiled without change to obtain an object deck. The example run described in the ADAGIO report was duplicated with faulty results. Ultimately, it was discovered that a FORTRAN statement was missing from the deck. After the missing card was inserted, results similar to the example were obtained. The ADAGIO program was operational on the SRI computer in July 1975.

A number of problems arose when ADAGIO was used with different criteria and modifications were made as necessary. It soon became apparent that major rewriting of the program would be necessary to approximate the manual calculations that were undertaken during the same time period. In particular, major modifications would be necessary to account for the highway net, to allow all of the hosting capacity to be used, and to permit the most remote risk areas to have priority in the allocation so as to result in more equal travel distances. Meanwhile, a hand allocation procedure was developed that satisfied the objectives of the analysis at a reasonable cost in time and effort. It was decided to abandon the attempt to produce a modified computer program and to perform the feasibility analysis on the basis of the hand allocation. Moreover, it was anticipated that a hand allocation procedure could be developed that would be practical to use in regional planning for crisis relocation in all densely populated areas of the United States.

Selection of Initial Planning Areas

Figure 1 is a map of the study area, DCPA Regions 1 and 2, with the areas at blast risk indicated by cross-hatching. In general, one observes a more or less continuous zone of blast risk along the Atlantic seaboard extending from Boston to Washington, D.C. To the west and south are sizable individual areas of blast risk in the vicinity of Albany, Syracuse, Scranton, Pittsburgh, York, Richmond, and Norfolk. Additionally, the area to the east of the main Boston-Washington risk corridor in Maryland, New Jersey, and Connecticut would be at fallout risk if surface bursts were used and hence was not available for hosting.

Our first concern in developing a manual allocation procedure was to consider how the study area could be subdivided into a reasonable number of planning areas, within each of which an independent allocation and feasibility analysis could be made. This was essential to make the analysis manageable. Consideration of highway routes showed that, other

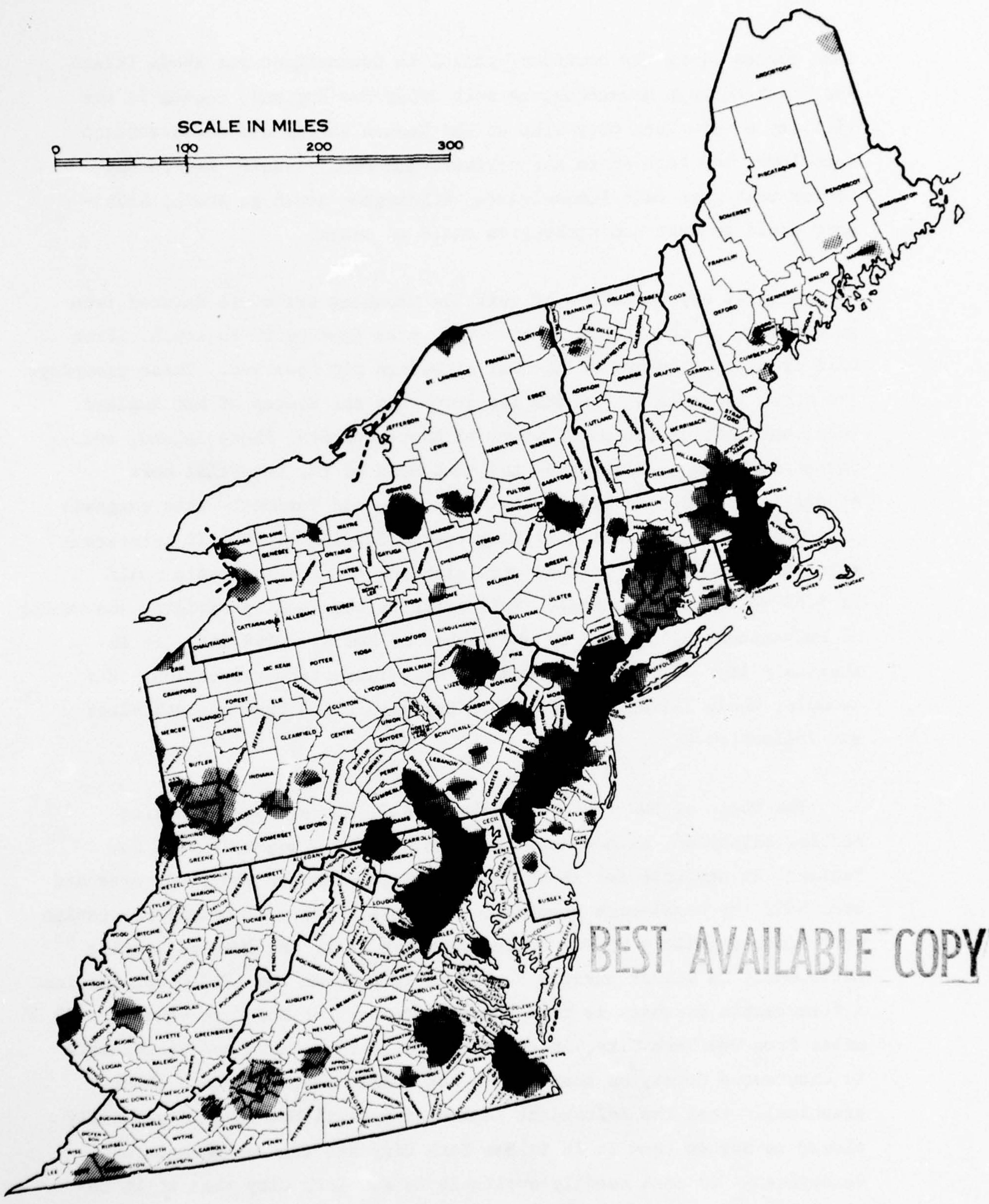

Figure 1 BLAST–RISK AREAS WITHIN THE STUDY AREA

than routes along the corridor, access in Connecticut and Rhode Island was north through Massachusetts into upper New England, routes in the vicinity of New York City went up the Hudson Valley and northwestward into lower New York State and northeastern Pennsylvania, New Jersey routes went west into Pennsylvania, Wilmington could go south, Baltimore could go west and Washington could go south.

A first approximation of suitable planning areas was deduced from an ordering of the States in the study area from north to south. From this ordering a number of natural groupings was observed. These groupings are shown in Table 2. In the top group are the States of New England. Note that most of the populations of Massachusetts, Rhode Island, and Connecticut are at blast risk and that most of the potential host population resides in Maine, New Hampshire, and Vermont. This suggests a flow of relocatees along highway routes leading north. If interstate relocation within New England were planned, the hosting ratio would be 5.63 relocatees per host. This ratio is obtained by dividing the number of relocatees, 9,554,981, by the number of hosts, 1,698,242. It is obviously impractical to contemplate only intrastate relocation. For example, Rhode Island does not have any population free of both blast and fallout risk.

The State of New York, taken by itself, has a somewhat easier hosting situation, with a hosting ratio of 4.64. Together with New England, it accounts for about half the population of the study area and over half the blast-risk population (Subtotal "B"). If crisis relocation were planned jointly in New England and New York, the average hosting ratio would be almost exactly 5, the ratio used in the ADAGIO calculation. A foreseeable drawback is that the western part of New York State is 400 miles from New York City, in event residents from there had to relocate to Chautauqua County as they did in the ADAGIO run. Figure 2 shows graphically that the Adirondack region of upstate New York is generally closer to Boston than it is to New York City and that northeastern Pennsylvania is more readily available to New York City than it is to Philadelphia.

Table 2

NATURAL STATE GROUPINGS AND HOSTING RATIOS

State	Population	Blast Risk (Evacuate)	Fallout Risk (Do Not Use)	Host Population	Host Ratio
Maine	992,048	329,494	-	662,554	
New Hampshire	737,681	319,957	81,195	336,529	
Vermont	444,732	83,093	-	361,639	
Massachusetts	5,689,077	5,199,509	237,888	251,680	
Rhode Island	949,723	912,276	37,447	-	
Connecticut	3,032,217	2,710,652	235,725	85,840	
Subtotal "A"	11,845,478	9,554,981	592,255	1,698,242	5.63
New York	18,177,475	14,868,035	107,602	3,201,838	
Subtotal "B"	30,022,953	24,423,016	699,857	4,900,080	4.98
New Jersey	7,030,306	6,490,144	395,019	145,143	
Pennsylvania	11,774,961	8,136,736	289,040	3,349,185	
Subtotal "C"	48,828,220	39,049,896	1,383,916	8,394,408	4.65
Delaware	547,962	425,530	42,076	80,356	
Maryland	3,918,471	3,344,361	274,089	300,021	
D.C.	756,510	756,510	-	-	
Virginia	4,644,384	2,799,638	-	1,844,746	
West Virginia	1,744,101	505,961	-	1,238,140	
TOTAL	60,439,648	46,881,896	1,700,081	11,857,671	3.95

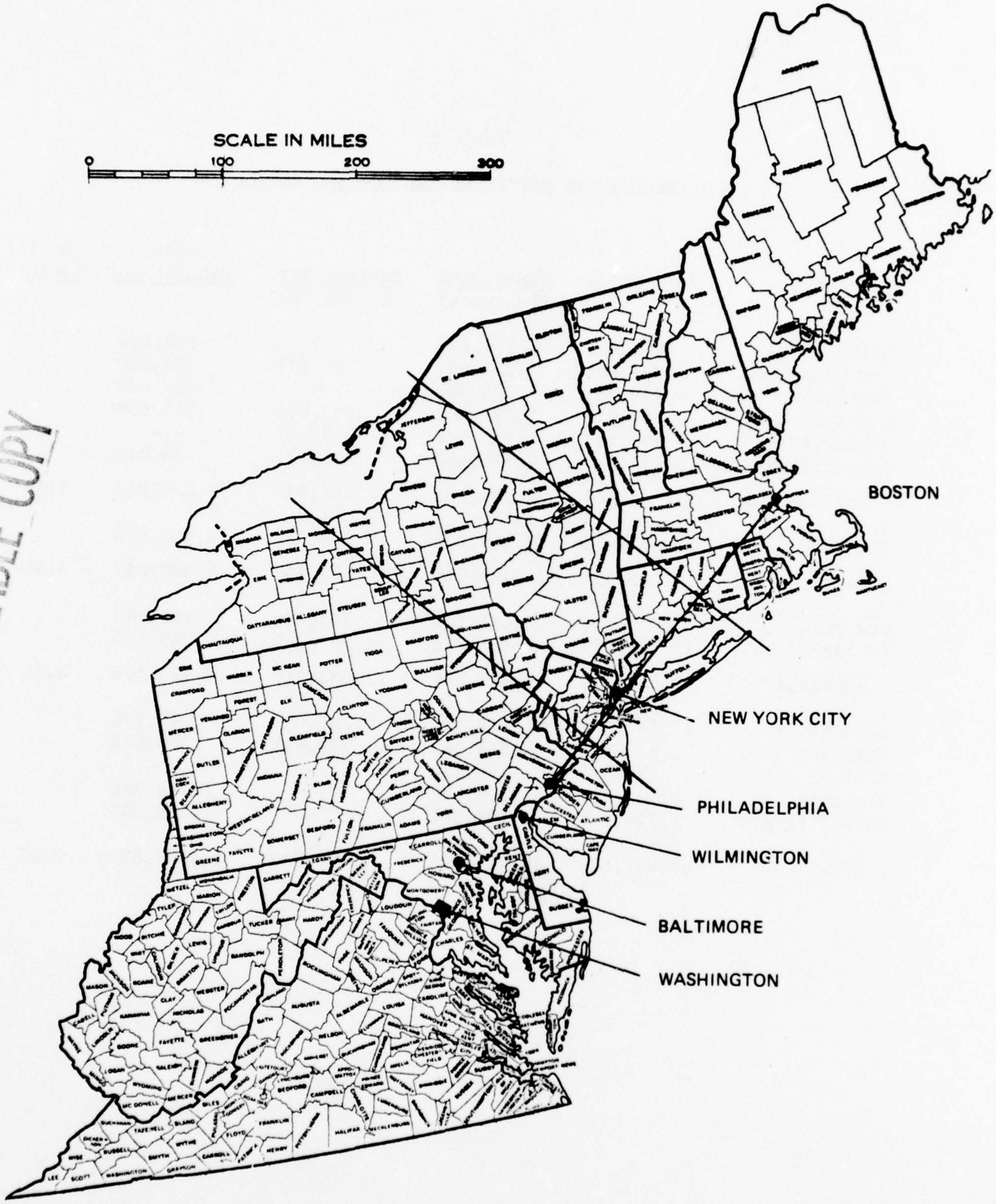

Figure 2 LOCATION OF HINTERLAND RELATIVE TO MAJOR CITIES

New Jersey and Pennsylvania make a natural grouping, both with respect to highway access and hosting situation. In general, the New Jersey risk population must move into Pennsylvania. The hosting ratio in New Jersey and Pennsylvania, taken jointly, is 4.19, even less crowded than in New York. Subtotal "C" shows the situation if planning is done jointly throughout Region 1 plus Pennsylvania. The average hosting ratio would be 4.65. This implies, of course, that all potential host counties are used, with some New Yorkers going into northeastern Pennsylvania and some New Englanders going into upstate New York.

Below the Mason-Dixon line, there is a very substantial host population. If all of the area, including the mountainous areas of West Virginia, were used, a hosting ratio of about 4 could be considered. Under these circumstances, however, some coastal residents would be moved a distance of 450 miles or more. Thus, there is a basic trade-off between living space and travel distance. Table 2 shows that a hosting ratio of 4 (four relocatees assigned for each host-area resident) is appropriate if the study area is regarded as one big planning area. Essentially all of the hosting space must be used at this hosting ratio. Thus, one must be willing to consider sending some New England residents south of the Mason-Dixon line. On the other hand, an average hosting ratio of 6 would confine the hosting of New Englanders within the New England area. Table 2 suggests that, as a first approximation, the study area could be divided into at least four natural groupings or planning areas: New England, New York, New Jersey-Pennsylvania, and the South. Hosting ratios could range from 4 to 6. Clearly, the hosting ratio used in the feasibility analysis (and in later planning, perhaps) can have a significant effect on relocation travel distances. What is the significance of a particular hosting ratio with respect to the practicability of the hosting itself?

Significance of the Hosting Ratio

One of the basic assumptions is that relocatees will be housed in congregate-care facilities rather than in residences. Thus, data on the availability of congregate-care space in the host counties may be used to judge whether the hosting ratios cited above are reasonable. Data from the 1974 Host Area Survey were available for this study. Figure 3 shows a plot of these data as a function of the resident population of the surveyed counties. Each dot represents the combination for a particular county; the resident population along the abscissa and the number of congregate-care spaces found along the ordinate. The straight-line represents the least-squares fit to these data points. The statistics of the fit are also given.[5]

In the survey, a "space" was taken as 40 square feet of usable floor area, the current peacetime emergency housing standard. The least-squares fit to the data suggests that, on the average, about 3.79 such spaces have been found for each resident in the counties surveyed. This is about 150 square feet of usable congregate-care floor area per capita. Not all of this space is likely to be available for housing of relocatees, however. Since the surveyors attempted to visit all nonresidential, nonfarm buildings and other structures, some of the space recorded is in buildings not readily usable for housing (sewage treatment plants, for example) or is in structures needed for other purposes (police stations and food stores, for example). DCPA planning guidance[6] suggests that only about two-thirds of the recorded congregate-care space should be considered available for housing relocatees. Therefore, for practical purposes, one can assume that there is, on the average, about 100 square feet of housing space per capita in the host counties.

On this basis, a hosting ratio of 4 would imply an allocation of 25 square feet of floor space per relocatee; a ratio of 5, 20 square feet; a ratio of 6, 16 2/3 square feet. Perhaps the best experience

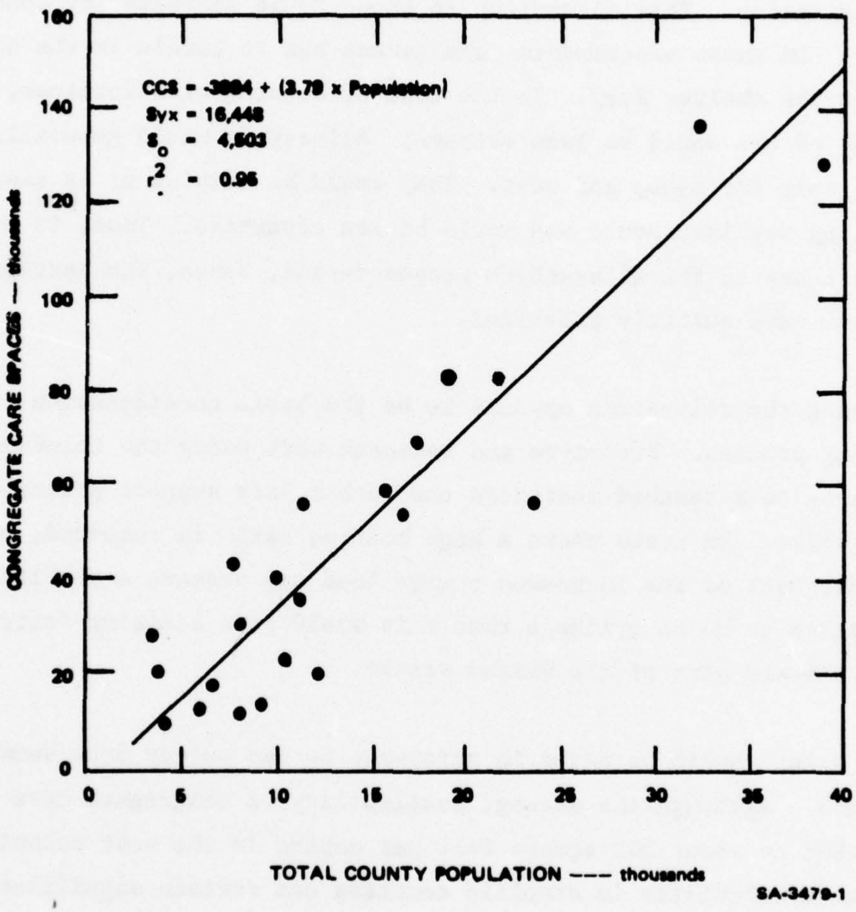

Figure 3 TOTAL COUNTY POPULATION AS A FUNCTION OF CONGREGATE CARE SPACES

available by which to evaluate these allocations lies in the large number of civil defense shelter occupancy experiments that have been undertaken in the past. Many such experiments have been conducted in which men, women, and children have lived for up to two weeks in shelter areas with a space allocation of 10 square feet per person, the current DCPA fallout shelter criterion. This allocation is known to be adequate for continued occupancy. In these experiments, shelterees had to remain in the shelter throughout the shelter stay. In the case of housing of relocatees, the conditions of use would be less extreme. Relocatees would generally use the space only for sleep and rest. They would be outside or at assigned tasks during daylight hours and would be fed elsewhere. Thus, it would appear that any of the allocations proposed—and, hence, the hosting ratios noted above—are entirely practical.

Housing the relocatees appears to be the basic consideration in the hosting process. Prototype and research work using the Colorado Springs area as a testbed indicates that other life support processes are manageable. In areas where a high hosting ratio is required, treatment or disposal of the increased sewage load may present a problem, but there appears to be no evidence that this would be a limiting factor in the northeastern part of the United States.

One point should be noted in reference to the survey data summarized in Figure 3. Although the average availability of congregate-care space may be taken as about 100 square feet per capita in the host counties, the actual availability in specific counties can deviate significantly from the average, especially in the more sparsely populated areas. A single hosting ratio can be used in a feasibility study or for general planning but the actual allocation of the risk population to the host counties should be based on a survey of resources and the application of a floor area allocation derived from the chosen hosting ratio. The implications of this conclusion for CRP programming are discussed further in Section III.

For this feasibility study, an average hosting ratio of 5 was chosen. This implies an allocation of 20 square feet of congregate-care floor area per relocatee.

Subdivision of the Study Area

Given an allocation of 20 square feet of living area per relocatee, the consequent hosting situation for the study area is shown in Table 3. Shown are the States ordered as in Table 2. Since the population at fallout risk does not enter into the allocation, only the population at blast risk and the host population are given. The hosting capacity in each State is obtained by multiplying the host population by 5, the hosting ratio chosen. Then, subtracting the population at blast risk gives the surplus or deficit in hosting capacity within each State. It can be seen that within New England there is an overall deficit of about a million spaces. New York, on the other hand, has a surplus of about the same amount. Noting the geographic relationship exhibited in Figure 2, and considering the highway access, five counties in northern New York State were combined with the New England States to form one planning area, Planning Area A. The remainder of New York State plus two counties, Susquehanna and Wayne, in northeast Pennsylvania was designated Planning Area B. Among the considerations leading to this choice was the probable difficulty of movement of residents of New York City westward through the densely populated Northeast New Jersey area. Movement would be restricted to the Hudson Valley routes and to those going northwest toward Binghamton. The two Pennsylvania counties were included because they were readily accessible, were close to New York City, and would reduce the need for relocation of New Yorkers to the western part of New York State.

There is excess hosting capacity in Pennsylvania, according to Table 3, a large part of which must be used by New Jersey. There is even more surplus at this hosting ratio below the Mason-Dixon line. Allocation

Table 3

HOSTING SITUATION IN STUDY AREA AT 20 SQ. FT. PER CAPITA

State	Blast Risk	Host Population	Capacity	Surplus (+) Deficit (-)
Maine	329,494	662,554	3,312,770	2,983,276 (+)
New Hampshire	319,957	336,529	1,682,645	1,362,688 (+)
Vermont	83,093	361,639	1,808,195	1,725,102 (+)
Massachusetts	5,199,509	251,680	1,258,400	3,941,109 (-)
Rhode Island	912,276	-	-	912,276 (-)
Connecticut	2,710,652	85,840	429,200	2,281,452 (-)
Subtotal "A"	9,554,981	1,698,242	8,491,210	1,063,771 (-)
New York	14,868,035	3,201,838	16,009,190	1,141,155 (+)
Subtotal "B"	24,423,016	4,900,080	24,500,400	77,384 (+)
New Jersey	6,490,144	145,143	725,715	5,764,429 (-)
Pennsylvania	8,136,736	3,349,185	16,745,925	8,609,189 (+)
Subtotal "C"	39,049,896	8,394,408	41,972,040	2,922,144 (+)
Delaware	425,530	80,356	401,780	23,750 (-)
Maryland	3,344,361	300,021	1,500,105	1,844,256 (-)
D.C.	756,510	-	-	756,510 (-)
Virginia	2,799,638	1,844,746	9,223,730	6,424,092 (+)
West Virginia	505,961	1,238,140	6,190,700	5,684,739 (+)
TOTAL	46,881,896	11,857,671	59,288,355	12,406,459 (+)

of host counties to Philadelphia-New Jersey, Baltimore-Wilmington, and Washington, D.C. is best made on the basis of minimizing travel distances on the major Interstate highways. It also appears that the hosting capacity in most of West Virginia and in the remote western part of Virginia would not be needed (except for local risk populations) at this hosting ratio.

The planning areas selected for the feasibility study are shown in Figure 4. Because there was a surplus of hosting capacity in Pennsylvania, Baltimore relocatees were allowed to move up Interstate 70 to its intersection with the Pennsylvania Turnpike, using eight counties in Pennsylvania as well as the three eastern panhandle counties of West Virginia. The remainder of Pennsylvania and New Jersey formed Planning Area C. Wilmington, Delaware was assumed to move south down the Delmarva peninsula to complete Planning Area D. The Washington metropolitan area was assumed to move south into Virginia (Planning Area E). Finally, Planning Area F consisted of West Virginia minus its three easternmost counties. Since West Virginia would have a low hosting ratio similar to States to the west, only Planning Areas A through E were included in the feasibility study. Within these five planning areas, allocations were made, average and maximum travel distances computed, and transportation adequacy assessed independently of each other. The results were evaluated as discussed in the next section.

Results of the Allocation

The allocation rules used in the feasibility analysis were based on the initial assumptions defined above; namely, hosting would be provided for 100 percent of the blast-risk population, commuting space would be assigned for 20 percent of the population of each risk county, and attention would be paid to the availability of transportation routes. The purpose of the allocation procedure was to minimize the disparity in travel distances among the various risk areas and thus to reduce the

Figure 4 INITIAL PLANNING AREAS

maximum distances assigned to these risk areas. One exception was made. If a risk county also had some hosting capacity within its boundaries, it was given prior rights to this capacity on the basis that, in actual planning, it would be politically difficult to explain to local authorities and the public why most of their risk population must relocate to some distance so that their "own" hosting capacity could be made available to a distant risk area in the interests of equity. This exception was not made in the six States of New England where counties are little more than judicial districts and are not otherwise significant political jurisdictions.

A hand procedure was developed to allocate risk-area populations to specific host counties using five times the resident population as the hosting capacity of the host counties. The first step in this procedure was to prepare a table of highway distances between the risk counties and the host counties, using the Rand-McNally mileage guide. The next step consisted of assigning 20 percent of the risk population to the nearest available host county, beginning with the risk county farthest removed from the hosting area. This step accounted for the assumed population associated with essential facilities in the risk areas. In the next step, additional portions of the risk populations were assigned hosting space in the next closest host counties, beginning with the farthest removed risk county, and this process iterated. Outlying risk areas were not assigned until the allocation had overrun them, forcing them to relocate in the direction of the main flow of the relocation. The partial assignments were repeated until all of the risk populations had been allocated to host areas.

The average relocation distance for each risk county was then determined by multiplying the number of people assigned to a host county by the distance between the risk and host counties, summing the products, and dividing by the total risk population. Maximum distances were also noted. Next, major variations were identified and corrected by reassignment. This step was terminated when, in the judgment of the analyst,

further improvement in the balance between risk counties would be marginal. Finally, average travel distance for the whole planning area was computed as above and the maximum travel distance among risk counties noted.

Initial results indicated that relocation distances in the southern part of the study area (Planning Areas D and E) were substantially less than in the other planning areas. Therefore, revisions were made in some of the planning area boundaries to shift the movement farther to the south. Charles and St. Marys counties of Maryland were included in Planning Area E, as shown in Figure 5. Planning Area D (Baltimore-Wilmington) was excluded from using part of Pennsylvania and allowed to use the upper part of the Shenandoah Valley of Virginia instead. New York City (Planning Area B) was given two more northern counties in Pennsylvania. The boundaries of Planning Area A were unchanged. This revision reduced the imbalance among the planning areas but did not eliminate it. The average and maximum travel distances for this revision are shown in Table 4. Relocation distances are greatest for the New York area. The *maximum* distance shown (319 miles) results from the final 62,000 people from Kings County (Brooklyn) being necessarily assigned to Allegheny County in western New York State. All of the risk populations were assigned in this allocation.

The commuting distances for the first 20 percent of the risk population in this allocation are shown in Table 5. Potential improvements to the allocation are discussed in Section III.

Transportation Analysis

Crisis relocation will depend on transportation services in four main classes: relocation, commuting, supply, and return. In the feasibility study, most of the analysis was devoted to relocation and commuting requirements since these appeared to dominate the question of feasibility. The last three basic assumptions discussed earlier

Figure 5 REVISED PLANNING AREAS

Table 4

RELOCATION DISTANCES*

Area	Metro	Average	Maximum
A	Boston	170	290
B	New York	188	319
C	Philadelphia	133	262
D	Baltimore	83	141
E	Washington	120	220

* Rand-McNally mileages for first revision.

Table 5

COMMUTING DISTANCES

Area	Metro	Average	Maximum
A	Boston	50	55
B	New York	77	94
C	Philadelphia	64	112
D	Baltimore	40	84
E	Washington	24	40

have a direct effect on the transportation analysis: that households possessing at least one auto would use the most suitable; that the goal would be to relocate the risk population within a three-day period; and that essential workers would commute to work at key facilities in the risk areas. All additional assumptions required for the transportation analysis were made to be consistent with the basic assumptions.

The objectives of the transportation analysis were to identify the transportation resources of the study area that could be used in crisis relocation services, to assess transport capacities, and to make a preliminary finding that available resources either do or do not have the inherent capabilities to perform the needed services. The principal transportation resources usable in crisis relocation are: (1) automotive vehicles--autos, trucks, and buses--and the road network, (2) rail vehicles and the rail network, (3) aircraft and airfields, and (4) pipelines. Table 6 lists the types of transportation resources applicable to crisis relocation services and indicates the approximate order of usefulness of each, as judged by the research team in light of the assumptions.

The primary resource for relocation and return will be "first automobiles"--the best vehicle available in occupied dwelling units having one or more automobiles or other light passenger vehicles, according to the 1970 Census. First autos are assumed to be used to the extent available and to the extent road capacity exists. All other transportation resources are considered secondary and are analyzed as necessary for study purposes. These resources include other automobiles owned by individuals, companies, and rental and sales agencies (called "second automobiles"), buses, trucks, trains, and aircraft.

Automobiles

Automobiles, drivers, roads, and related resources are by far the most valuable and versatile "system" available for passenger movements and require first consideration in every risk area. In the study area,

Table 6

APPLICABILITY OF TRANSPORTATION RESOURCES

Resources	Relocation	Commuting	Supply	Return
Automobiles	1	1		1
Buses	2	2		2
Passenger trains	3	3		3
Aircraft	4			4
Trucks	5		1	
Freight trains	6		2	
Pipelines			1	

NOTE: Numbers indicate order of usefulness.

there are more than 27 million automobiles to serve about 60 million people.[7] In theory, everyone could board an automobile with a driver at one time, with millions of seats remaining vacant. However, automobiles and drivers are not uniformly distributed among all classes of society, among all risk areas, and within risk areas. The limited mobility classes--the young, the old, the poor, and the handicapped--and the residents of densely developed areas with good transit service are often carless. The New York area offers an extreme example of differences among districts: in Manhattan, only 22 percent of the households have one or more autos, while in Suffolk County, the figure is 93 percent. On the other hand, small cities and the suburbs of large cities exhibit considerable uniformity in the availability of automobiles, with about one vehicle for every two residents.

By assuming that each household having one or more automobiles will use its first auto for relocation, the average load factor to be assumed is necessarily determined by the average household size rather than an estimate of carrying capacity. In the large cities of the Northeast Corridor, this load factor varied from 2.2 persons to 4.0 persons per vehicle. Observations of passenger cars in vacation travel usage give average loads of about 3 1/3 people with baggage. Higher loadings were presumed in the OSPs of the 1950s.

Fuel

Automobiles needed for relocation can be fueled and serviced within the risk areas during the three-day movement phase--there is sufficient fuel and service capacity. The reasoning leading to this conclusion follows. National statistics indicate that the average automobile is driven 33 miles per day.[8] Most vehicles have a range of about 250 miles; e.g., a car making 12.5 miles per gallon will have a 20-gallon tank. Most drivers do not wait until the tank is empty to refuel. Hence, the average frequency of service is every five days or so, rather than

the 7 1/2 days required to consume a full tank of fuel. That is to say, the automobile servicing system is normally accustomed to handling about one-fifth of the automobile fleet each day. On the other hand, first automobiles constitute about three-fifths of the entire fleet. Therefore, the autos needed for relocation can be refueled and serviced in three days--the rate is the same under both normal and crisis conditions.

It also appears that the amount of fuel in the risk areas at the start of relocation will normally be sufficient to fill all tanks of the vehicles needed for relocation. According to FEA personnel, the normal supply of gasoline in the United States is sufficient for about 30 days. It appears that at least a five-day supply is normally in the final distribution stages; i.e., in service stations, delivery trucks and distributors' tanks within the risk areas. The fuel normally sold in a three-day period moves the automobiles of the nation 100 miles each on the average. The same amount of fuel would be sufficient to move three-fifths of the fleet about 167 miles on the average. It can be seen from Table 4 that this average distance is exceeded substantially only in Planning Area B, the New York area. On the other hand, the normal range of a tankful of fuel is exceeded in both the Boston and New York planning areas. Thus, enroute refueling would be essential in these areas.

Highway Capacities

Normal highway capacities are known to vary over a considerable range depending upon the highway type, number and width of lanes, control of turning and crossing traffic, presence of grades and curves, the mix of vehicular types, the presence of distraction, the behavior of individual drivers, and the size and performance of vehicles. A 1963 study dealing with relocation problems[2] used a capacity factor of 1,000 cars per hour per lane, which was assumed as an average capacity for all roads, good and bad. No separate estimate was made of possible loss of

capacity through congestion, accidents, or lack of demand. Thus, if the 1963 factor were to be used in this feasibility study, each lane of a relocation route would be assumed to accommodate 72,000 automobiles in a three-day period.

In the present study, it was decided to use a somewhat more detailed set of capacity factors for two main reasons. First, in the period since 1963, many freeways and other high-capacity roads have been constructed--the estimating procedure recognizes three classes of highways and states a capacity factor for each. Second, it is well known that the flow of traffic on highways cannot be maintained at uniform high rates approaching theoretical capacity over a long period of time. Hourly capacity factors were chosen to be conservative in comparison to theoretical limits and observed traffic, and should be exceeded from time to time during a relocation. However, the potential for severe loss of capacity through accidents, congestion, and other mishaps more than offsets the potential for occasional small gains. To allow for this inequality, it has been assumed that the attainable volume of traffic during a 24-hour period is equivalent to 20 hours at the stated capacity factor for each lane and road type.

The Highway Capacity Manual,[9] published in 1965, contains a wealth of data on the capacities of typical highways under various conditions and is accepted as the standard authority on the subject. Capacities and speeds are related to one another in a classification scheme that defines six levels of service, A through F. The factors employed in the feasibility analysis were derived from the Highway Capacity Manual, with judgmental adjustments explained below.

Freeway Capacities

Under favorable conditions, some urban freeways are observed to carry more than 2,000 passenger cars per hour per lane during the peak

hour of traffic. In many such cases, most of the drivers are commuters engaged in trips made hundreds of times each year. Conditions during a relocation would be much less favorable. Therefore, a lower factor appears appropriate. Level of service D appears to represent the best balance of values for relocation traffic on modern freeways having 12-foot lanes. Levels of Service A, B, and C have higher average speeds but lower capacities. Level of Service E involves lower speeds, unstable flow including stoppages, and, hence, the risk of lower daily capacity.

According to the Manual, Level of Service D provides a speed of about 40 mph and sustained maximum service volumes in the range of 1,400 to 1,650 passenger automobiles per hour per lane depending upon conditions. The Manual also states that "passenger vehicles stopped in line will rarely get under way at a faster rate, on the average, than 1,500 passenger cars per hour per lane . . ."

It is noteworthy that the Bureau of Public Roads (BPR) addressed the problem of highway capacity and usage for relocation in a study prepared for the Federal Civil Defense Administration in 1956.[10] That study indicated an "accepted practical capacity of 1,500 vehicles per hour per 12-foot lane for multilane highways with operating speeds of 35 to 40 miles per hour." Thus, the BPR civil defense study and the 1965 Manual are in reasonable agreement.

These data are offered as justification for the following planning factors for controlled-access multilane divided highways: 1,500 passenger vehicles per hour per lane; 30,000 passenger vehicles per day per lane; and 90,000 passenger vehicles per lane over a three-day period. In detailed planning, of course, local conditions may dictate a different factor and the final choice should be made by local planners.

Highways Without Access Control

Highways other than freeways have been classed in two groups: two-lane routes and multilane divided, two-way routes. According to the Manual, the highest observed traffic on a two-lane two-way rural route was 1,224 vehicles per hour in the heavy direction and 553 vehicles per hour in the light traffic direction for a total of 1,777 vehicles per hour on the route. Other two-lane two-way routes exhibit similar total flows but with more equal divisions between directions. Generalized information presented in the Manual indicates that a two-lane two-way rural highway under ideal conditions operating at Level of Service D with an average speed of 35 mph would carry maximum hourly rates up to 1,700 passenger cars, total, both directions, for brief periods. The division of traffic between directions can vary over a wide range with little effect on total road capacity.

Multilane divided rural highways are observed carrying volumes up to 1,774 vehicles per hour per lane. Generalized data indicate that each lane of such a highway would carry up to 1,800 autos per hour under ideal conditions and for brief periods of time. In this study, highways without access control were assigned lower capacity factors to allow for various conditions that will cause actual capacities to be substantially below the maximum observed or ideal flow rates. Among these are narrow lanes, limited sight distances, grades, and, most important, intersections. The existence of intersections to accommodate crossing and turning traffic causes most highways without access control to have significantly lower capacities per lane than freeways or unimpeded rural road.

Based on the foregoing considerations, the following capacity factors have been chosen for highways without access controls for use in the feasibility analysis. Each two-lane two-way highway is assumed

to carry 900 passenger cars per hour in the outbound direction and 100 vehicles inbound (traffic control, public safety, tow trucks, and other essential traffic). Thus, the total flow assumed is 1,000 vehicles per hour on two-lane undivided highways. A multilane rural highway is assumed to carry 1,200 passenger cars per hour per lane. As with freeways, the daily capacity is assumed to be equivalent to 20 hours at the planning factor rate. The three-day capacity of each lane is equivalent to 60 hours at the planning factor rate.

Medium-Sized Risk Areas

Risk areas with populations of 1 million or less pose simple transportation problems in all stages of a crisis relocation in comparison with the very large metropolitan areas. This assertion is borne out by the prototype experience of DCPA where normal use of available highways, assuming a gross lane capacity of 1,000 cars per hour per lane, resulted in estimates of relocation movement time substantially less than three days. Table 7 presents three illustrative cases to dimension the problem. The illustrative areas have been given typical characteristics of areas of 250,000, 500,000 and 1 million persons. Typically, 85 to 95 percent of all households possess one or more automobiles. Household sizes range from 2.8 to 3.8 persons. As can be seen, most of the population can relocate in first automobiles. Using the lane capacities discussed above, Area X could be evacuated in three days or less by use of two two-lane undivided highways or a single multilane divided highway. Area Y would require three undivided rural highways or one multilane route. Area Z, the typical risk area of about 1 million persons, would require one Interstate or freeway route and one other divided highway or three undivided two-lane two-way highways. Thus, the lanes required for relocation by first auto are quite low in comparison with the highways that would ordinarily be found leading from cities of the sizes considered. Thus, the transport of those requiring other means by bus or truck is unlikely to tax the highway system. Non-highway modes of transport are

Table 7

TYPICAL AUTOMOBILE RESOURCES IN MEDIUM-SIZED RISK AREAS

	Area X	Area Y	Area Z
Population	250,000	500,000	1,000,000
Households	80,000	130,000	350,000
Households with one or more automobiles	72,000	123,500	297,500
Automobiles owned	125,000	275,000	450,000
Population relocatable by "first" auto	225,000	475,000	850,000
Population requiring other means	25,000	25,000	150,000
Automobiles not used	53,000	151,500	152,500

unlikely to be needed. It may be noted from Table 7 that the number of unused autos exceeds the number of people requiring transportation in all cases. Since national statistics show that there are about as many drivers as there are automobiles,[7] one might be tempted to explore how these second automobiles might be put to use. In this feasibility analysis, we did not assume any use of these vehicles.

Large Risk Areas

Having concluded that the unique transportation problems of the Northeast Corridor, if they exist, are most likely associated with the very large risk areas, the feasibility of transportation was studied only in such areas. The automobile resources in the large seaboard risk areas are summarized in Table 8. Two questions of feasibility are immediately apparent: (1) Does the highway system leading from these risk areas to the hosting counties have the capacity to handle the large numbers of first automobiles in a three-day period? and (2) Are other means of transportation adequate to relocate the large numbers of people without private transportation? In the New York area, about 40 percent of the population is carless and in several other areas those requiring other means of transportation constitute about 20 percent of the population.

The method used to test the adequacy of the highway system was the cordon method. In this approach, a complete transportation analysis is not attempted. Rather, a cordon line is established between each risk area and its allocated host counties at a location where the relationship of available lanes to traffic volumes appears to be most restricted. For this purpose, the general relocation flow was noted from the allocation data and the highway net in that direction evaluated. Casual observation indicated that many routes were available within the large risk areas and that surplus routes were generally available in most host counties. Thus, the cordon lines were set up fairly near the major risk areas.

Table 8

AUTOMOBILE RESOURCES IN LARGE RISK AREAS

	Boston-Providence	New York	Philadelphia-So. New Jersey	Baltimore-Wilmington	District of Columbia
Population	5,163,200	11,439,900	5,442,700	2,398,700	2,789,300
Households	1,601,600	3,862,600	1,700,800	732,300	879,800
Households with one or more automobiles	1,271,800	2,125,800	1,325,500	571,000	714,400
Automobiles owned	2,455,000	3,364,700	2,366,400	999,500	1,267,900
Population relocatable by "first" auto	4,067,300	6,613,400	4,241,600	1,887,300	2,264,000
Population requiring other means	1,095,900	4,909,400	1,201,100	511,400	525,300
Automobiles not used	1,183,200	1,238,900	1,040,900	428,500	553,500

The cordons chosen for analysis are shown in Figure 6. In the Boston area, the risk population to be moved, mostly north, includes not only the eastern Massachusetts and Rhode Island risk areas but also Nashua and Manchester in New Hampshire. Thus, the cordon chosen extends across New Hampshire from just below Portsmouth and below Concord to the Vermont border. The cordon for the New York area is the northern boundary of Westchester and Rockland Counties.

In the Philadelphia area, the cordon line runs from the New Jersey border on the north to the western border of Delaware County on the south. In planning area D, the cordon of greatest constraint appears to be to the west of Baltimore, north of Washington. The Washington cordon lies in Virginia to the south.

These cordons were established with an element of judgment and there is some possibility that they may not represent the limiting capacities. They should, however, give results that are quite close to those that might come from a more detailed analysis.

Relocation Movement Times

The results of the cordon analysis are shown in Table 9. The populations and first automobiles that must cross the cordons were calculated from the allocation data and the census information given in Table 8. In the New York, Philadelphia, and Washington planning areas, all of the first automobiles must cross the cordons. In the Boston/Providence area, some vehicles go to Cape Cod and others are destined for host counties below the cordon. In the Baltimore/Wilmington area, only 55 percent go west across the cordon; the others go south into the Delmarva Peninsula.

It can be seen from Table 9 that only in the two southern planning areas are there sufficient outbound lanes to permit relocation in a three-day period. In the others, the relocation time will range from

Figure 6 KEY CORDONS

Table 9

INITIAL CORDON COUNT

	Boston-Providence	New York	Philadelphia-So. New Jersey	Baltimore-Wilmington	Washington
Population relocatable by first automobile	4,067,300	6,613,400	4,241,600	1,887,300	2,264,000
First automobiles	1,271,800	2,125,800	1,325,500	571,000	714,000
Autos across cordon	997,500	2,125,800	1,325,500	312,000	714,400
Available lanes	10	14	13	5	11
Three-day capacity	756,000	1,080,000	882,000	342,000	738,000
Shortage	241,500	1,045,800	443,500	OK	OK
Relocation period (days)	4	6	4 1/2	3	3

4 to 6 days. These results assume normal use of the highways with respect to numbers of outbound lanes and degree of access control. Other alternatives are considered in Section III.

The foregoing analysis covers only the first automobiles and does not consider the transportation needs of the remaining population. For example, in the case of New York, six days is the estimate of the movement time for the 60 percent of the population that have access to an automobile. To the extent that the remaining 40 percent are relocated by bus or truck, their movement would compete for highway capacity with the first autos, thus adding to the length of the movement phase. Therefore, we will evaluate the capacities of the non-highway modes of transportation before having recourse to use of buses and trucks.

Rail Transportation

Urban rail transit, suburban commuter trains, intercity passenger trains, and freight trains are the subclasses of rail transportation of interest.

Urban rail transit exists in Boston, New York, Newark, Philadelphia, Pittsburgh, and Washington. The vehicles are restricted to established routes that are entirely within the risk areas. Travelers who cannot be relocated in autos could use the urban rail transit as one stage of a several-stage relocation trip. Urban rail may also be useful for commuting and return operations. Capacities vary from line to line and will need to be treated individually in detailed plans.

Suburban commuter trains are used on a significant scale in the Boston, New York, and Philadelphia areas. In most cases, the trains use electric propulsion and are restricted to established routes. Some could be rerouted during a crisis and service increased on those routes contributing to the relocation. Commuter trains can provide services similar

to urban rail transit but have the advantage of extending moderate distances into host counties in some instances. Commuter trains can carry loads in the order of 1,000 seated passengers. The planning factor used here is 1,500 passengers per train with crowding. Each train can make numerous round trips and each route can accommodate many trains.

AMTRAK and the Southern Railroad operate intercity passenger trains in the Northeast Corridor study area. Most of the traffic is among the major seaboard cities--Washington, Baltimore, Philadelphia, New York, and Boston--and has little application to relocation operations, which are mainly concerned with movement away from the seaboard. Also, many AMTRAK trains are electrically powered and limited to their established routes. However, intercity trains operate between some risk and host areas. Of particular interest in the feasibility study are AMTRAK routes out of the New York and Philadelphia areas to the north and west, including the Penn Central, Erie-Lackawanna, and Reading lines now part of CONRAIL (there is no rail passenger service north of Boston). Intercity passenger trains are normally limited in length to 18 cars and attempting to lengthen trains would probably be ineffective. Normal train capacities are about 900 to 1,000 seated passengers plus baggage. We will use a planning factor of 1,500 passengers per train to allow for crowding.

Freight trains can be used for the transportation of passengers under emergency conditions, such as would exist when crisis relocation would be undertaken. In the United States, there are 328,000 "plain" box cars potentially usable by relocatees. There are also a total of 287,000 special box cars, refrigerator cars, and stock cars, some of which are usable for passengers. A substantial fraction of the railway car inventory is ordinarily empty and in usable condition at any moment in time.

For feasibility analysis, it will be assumed that about 200,000 cars throughout the nation are potentially available for passenger service in a crisis, approximately one per 1,000 persons, and distributed

more or less as the population. There are more than 28,000 diesel-electric locomotives in the United States. It will be assumed that they are well-distributed and that priority for their use would be assigned to the relocation operation.

All of the major risk areas have multiple rail lines leading to their host areas. A 50-foot box car would accommodate about 50 passengers at an average of 10 square feet for each passenger and baggage. The average freight train contains about 65 cars but the time to load and unload passengers on freight trains of that length would be excessive. Consequently, it is assumed that freight trains adapted to passenger service will be limited to 30 50-foot box cars or their equivalent and will carry 1,500 passengers.

Commuter and intercity passenger trains can be expected to travel at 40 mph. An hour will be allowed for turnaround at each end of the trip. Trains will be in the duty cycle 20 hours each day. Although freight trains typically make average speeds of 20 mph for entire journeys, enroute delays in relocation service can be minimized and speeds of 40 mph appear practicable. Indeed, a common average speed will be essential on lines where mixed passenger and freight trains are to be employed. Loading and unloading times are assumed to be two hours each. Freight trains used for passenger service will not make round trips unless the supply of cars in the risk area is low enough to require repeated use of the same cars. This is likely only in the Boston area. Loading facilities in the risk areas appear sufficient to permit trains, either passenger or freight, to depart on one-half hour headways. Thus, the capacity of a single outbound rail line over a three-day period can be taken to be 180,000 persons and baggage.

Airlift Capabilities

Commercial aircraft can make a significant contribution to the relocation of people from the major risk areas. In the United States,

there are about 2,320 fixed-wing commercial aircraft.[11] A substantial part of this fleet normally operate in the study area. The capacities of commercial aircraft vary from about 20 to 400 seats. In 1973, the average capacity of aircraft operating out of LaGuardia and John F. Kennedy International airports was about 150 seats. At airports such as Washington National, the average is probably nearer 125 seats.

Airfields in host counties will usually govern the size of the aircraft that can be used for relocation. The average load will depend on the types of aircraft employed and is taken as 100 passengers for the purposes of this study. For short flights (a few hundred miles), all commercial aircraft have greater weight-carrying capacity than seating capacity for passengers. It would be possible to increase passenger loads by about 50 percent above the normal if the requirement were waived that all passengers must be seated and must use seat belts. Except in bad weather, allowing passengers to stand or sit on the floor would probably not result in an unacceptable risk to either passengers or aircraft. Certainly, many relocatees would prefer an hour of travel under these conditions to many hours of travel in a box car or truck.

Airports and supporting facilities, experienced personnel, and fuel are relatively abundant in all the heavily populated risk areas. Airports suitable for the largest commercial aircraft are available in Boston, Hartford, New York, Philadelphia, Baltimore, and Washington. Other airports in risk areas can accommodate intermediate and small models. There are a relatively small number of airports in the host areas that can handle commercial aircraft and they are generally limited to the intermediate and smaller types. In an emergency, the capacities of those airports to handle air traffic can be increased quickly by flying in additional skilled personnel and portable equipment needed to increase the capacity to discharge passengers and handle baggage.

Aircraft will be especially valuable in moving evacuees to relatively distant host counties. At a distance of 250 miles, flying time is about 40 minutes in each direction, and an additional 100 miles would add only about 12 minutes to each flight. For the 250-mile distance, which is well above the average relocation distance in all planning areas, the entire round-trip cycle would require an average of 2.3 hours. Aircraft must be out of this duty cycle several hours each day for service and repair. Therefore, aircraft employed in relocation operations could average only about eight round trips per day. This would involve about 11 hours of flight time, 19 hours in the duty cycle and about 5 hours per day reserved for maintenance. Using the 100-person planning factor, about 2,400 persons could be relocated by each aircraft over the three-day movement period. The handling capacity of the airports would control the airlift capacity rather than the number of aircraft available. Small airports in the host counties are assumed to be able to handle 120 arrivals per day: one arrival every 10 minutes on the average throughout a 20-hour operating day. Major risk-area airports dispatch as many as 800 aircraft per day and probably could increase this capacity by 50 percent if necessary. For the feasibility analysis, the typical host county commercial airfield can handle about 36,000 relocatees over a three-day period. Our identification of suitable airfields is intentionally conservative.

The number of flying hours per plane and the quantity of fuel to be loaded at the risk-area airports are not exceptionally high in comparison with peak periods of air travel under normal conditions. Therefore, fuel and maintenance should not restrain operations.

Summary of Non-Highway Relocation Capabilities

Using the planning factors discussed above, the three-day capacities of non-highway modes of relocation for the five largest seaboard urban centers are shown in Table 10. There are two rail lines leading north

Table 10

NON-HIGHWAY RELOCATION CAPACITIES (THREE-DAY PERIOD)

	Boston-Providence	New York	Philadelphia-So. New Jersey	Baltimore-Wilmington	Washington
Population requiring other means of transportation	1,095,900	4,909,400	1,201,100	511,400	525,300
Passenger rail	none	180,000	360,000	none	13,500
Freight rail	360,000	360,000	180,000	540,000	166,500
Airlift	288,000	324,000	180,000	72,000	108,000
Shortage	447,900	4,045,400	481,100	none	237,300

from the Boston area, one into New Hampshire and one into Maine. Since there is no passenger service on these lines, freight cars would be the primary conveyances. There are eight airports in the host area served by scheduled airlines. (Airports served by commuter lines have not been included although some of these might be able to handle the larger aircraft.) In the New York case, there are two Penn Central rail lines up the Hudson valley and the Erie-Lackawanna line to the Binghamton host area. The majority of the relocatees must be transported in freight cars. Nine host-area airports served by scheduled airlines could relocate about 324,000 persons.

In the Philadelphia area, three rail lines are available. Because of the relatively large passenger and commuter rail service, the majority of the rail relocatees could travel on passenger cars. Only five commercial airfields in the host areas are served by scheduled airlines. Two rail lines lead west from Baltimore and one south from Wilmington. No passenger service is available. Only two commercial airports are available, Salisbury to the south and Hagerstown to the west. While the rail capacity ostensibly meets the Baltimore-Wilmington need, some airlift may be needed if the rail capacities cannot be balanced against the location of those requiring transportation. From Washington, rail passenger service is available to Charlottesville and Staunton in the host area but is likely to carry only a small part of the 180,000 capacity of the line. Three airports, Charlottesville, Staunton, and Lynchburg, could receive airlift relocatees.

It can be seen from Table 10 that only the Baltimore-Wilmington requirement is likely to be satisfied by the rail and air modes. However, the potential requirement for bus and truck transportation is cut about in half for Boston, Philadelphia, and Washington. In the New York area, over 4 million persons remain to be transported on the highways.

Buses and Trucks

Our analysis as summarized in Table 10 indicates that substantial numbers of people, 4 million in New York alone, must be relocated by highway vehicles other than first automobiles. Although a vast resource of second automobiles will remain in the risk areas, a reliable--or even plausible--way to mobilize and use these vehicles is not apparent. Even if a ready means were available, these additional passenger cars are likely to strain the capacity of the highway system more than the comparable fleet of buses and trucks. And truck and bus drivers appear to be available in large numbers in relation to need. Many vehicles normally have more than one trained driver, and the drivers of many trucks not suitable--or needed for relocation or supply--will be idle. Of course, drivers are likely to be torn between their occupational and family duties during a crisis, especially when a relocation is directed. Detailed planning along the lines discussed in current DCPA planning guidance[12] will be needed to assure that drivers' dependents are relocated in a manner to maintain the family integrity.

In the study area, there are about 109,300 buses.[7] For present purposes, 31,600 of these--the diesel or butane fueled vehicles--are classed as "large buses" and are assumed to be capable of transporting 40 relocatees and luggage, based on an average seating of 47 persons in intercity buses and 52 in urban buses. The remaining 77,700 are classed as "small buses". These are mainly school buses, many of which carry up to 66 children. It is assumed that small buses are capable of transporting an average of 30 passengers and luggage in relocation operations. The distribution of large and small buses among the States in the study area is given in Table 11.

There are more than 3.9 million trucks in the study area, distributed as shown in Table 12. About 217,000 vehicles are classed as tractor trucks. These vehicles are designed to tow semi-trailers and

Table 11

BUSES

	Large[1]	Small[2]	Total
Connecticut	1,574	5,560	7,134
Rhode Island	235	696	931
Massachusetts	2,607	5,679	8,286
New Hampshire	185	966	1,151
Maine	174	1,874	2,048
Vermont	80	916	996
New York	11,176	18,839	30,015
New Jersey	2,927	7,828	10,755
Pennsylvania	6,476	15,331	21,807
Delaware	258	1,049	1,307
Maryland	1,816	8,290	10,106
District of Columbia	1,585	747	2,332
Virginia	1,839	8,416	10,255
West Virginia	671	1,560	2,231
TOTAL	31,603	77,751	109,354

[1] Commercial buses, diesel and butane fueled.

[2] All other.

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, p. 39 (1973).

Table 12

TRUCKS

	Tractor Trucks	Other Trucks	Total Trucks
Connecticut	8,127	152,045	160,172
Rhode Island	4,936	59,444	64,380
Massachusetts	17,339	273,220	290,559
New Hampshire	3,379	71,832	75,211
Maine	4,183	115,793	119,976
Vermont	1,846	47,060	48,906
New York	34,856	722,690	757,546
New Jersey	32,645	359,866	392,511
Pennsylvania	66,386	840,153	906,539
Delaware	6,234	48,334	54,568
Maryland	13,965	301,237	315,202
District of Columbia	472	17,283	17,755
Virginia	16,315	473,331	489,646
West Virginia	5,838	218,331	223,949
TOTAL	216,521	3,700,399	3,916,920

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, p. 38 (1973).

full trailers. In the entire commercial fleet there are several times as many trailers as tractors. A large fraction of the trailers are usable for carrying relocatees. The 3.7 million classed as other trucks include a wide variety of sizes and characteristics. Many are equipped for special cargos and may not be usable for relocation operations. Also, most of the smaller trucks may not exist in fleets of substantial numbers, making it doubtful that operational arrangements could be made to mobilize them in a crisis emergency. Many, however, will be suitable and accessible with reasonable planning. Notable are large vans for the movement of household goods and delivery vans operated by department stores, furniture and appliance stores, bakeries, supply houses, and parcel delivery companies.

It is assumed for the feasibility analysis that half the tractor trucks and other trucks can be used to move passengers during relocation and return operations. The capacity factors used for tractor truck and trailer combinations are 30 passengers and baggage; for other trucks, an average of 10 passengers and baggage is used.

Buses and trucks are larger, have less power per unit of weight, and are less agile than automobiles. During a relocation conducted largely in automobiles, some truck traffic—up to 1 percent of the vehicles—can be introduced without reducing appreciably the highway capacities for autos. As can be seen from Table 9, the numbers of buses and trucks that could be introduced into the movement of first automobiles are not insignificant; in the New York area, over 21,000 large vehicles carrying perhaps 750,000 persons could be added during the projected six-day period. In the Baltimore and Washington areas, there is some excess highway capacity as well. For the most part, however, bus and truck transport must be added to the first automobile movement, either by reserving some outbound lanes for them or by scheduling them to move after the automobile movement is essentially complete. In these circumstances, lane capacities (derived in a parallel manner to that described for autos) are taken to be 225 large vehicles per hour

(13,500 in three days) for two-lane, two-way highways, 300 per hour on multilane divided highways, and 375 per hour on limited-access freeways. The capacity for the two-lane, two-way rural highway is to be compared with the 900 automobiles per lane per hour discussed earlier. If round trips are required, so that traffic is about equal in both directions, the lane capacity would be reduced to about 125 large vehicles per hour.

The results of the analysis are shown in Table 13. The population figures are drawn from the bottom line of Table 10; that is, they represent the numbers of people that cannot be accommodated by first automobiles or by rail and air transport. The single trip capacities for buses and trucks have been obtained by applying the vehicle capacities to one-half the inventory of vehicles in the risk areas, assuming that these vehicles are distributed in proportion to population. The required number of bus trips is obtained by dividing the population to be transported by the single-trip bus capacities. The number of bus plus tractor trips is obtained in a similar fashion. If both large and small buses and tractor trucks are assumed to be used, a single trip is sufficient except in the New York area.

Summary of Movement Times

The final line in Table 13 gives the total relocation time for both first autos and large vehicles, as dictated by highway capacity constraints. Only buses and tractor trucks are used as needed, as the assumed capacity of other trucks (10 persons) does not make their use attractive in terms of minimizing movement time. Buses and tractor trucks are assumed to travel after the first automobile movement; that is, no credit is taken for the possibility that many large vehicles could be introduced into the automobile movement without a significant effect on capacity. The increased movement time over that for first automobiles only (Table 9) is minor except for the New York area. The

Table 13

USE OF BUSES AND TRUCKS

	Boston-Providence	New York	Philadelphia-So. New Jersey	Baltimore-Wilmington	Washington
Population requiring bus or truck transport	447,900	4,045,400	481,100	none	237,300
Large buses (one trip)	83,640	280,280	105,160	44,520	98,720
Small buses (one trip)	151,230	354,360	196,290	149,550	143,430
Tractor trucks (one trip)	271,080	655,650	418,290	178,020	114,660
Other trucks (one trip)	1,398,450	4,531,270	1,669,750	945,390	966,850
Bus trips	2	7	2	-	1
Bus + tractor trips	1	3	1	-	1
Total relocation time (first autos, buses, and trucks)	4 1/2 days	7 1/2 days	4 3/4 days	3 days	3 days

times given are somewhat overstated because the non-highway capacities (Table 10) are for a three-day period. If full use of non-highway modes were made during a comparable movement period, one large-vehicle round trip could be eliminated in the New York area, thus reducing the movement time to about seven days.

Feasibility of Commuting

In this analysis, we selected somewhat arbitrarily 20 percent of the population as representing essential workers and their families. This fraction was relocated to the nearest available hosting areas to minimize the distances required to commute to and from the risk areas. The resulting average and maximum commuting distances for each of the major risk areas are given in Table 5. Generally, the average commuting distances are reasonable, especially since access to the risk areas is by means of limited-access freeways in almost all cases. The maximum distances in Planning Areas B and C, however, must be considered excessive. In the New York area, the problem is that, without any hosting capacity on Long Island, essential workers from Suffolk County key facilities must commute at the very least from Putnam County (see Figure 5). In Planning Area C, the most severe problem is in northeast New Jersey (and Atlantic City) where most essential workers must be hosted in Pennsylvania.

It was assumed that eight percent of the population (20 percent of the work force) would be required to commute. In typical areas, it is expected that the first automobiles used to relocate essential workers and their dependents will provide abundant capacity for car-pool commuting. For example, if 100 essential workers and dependents relocated by auto, the workers could commute to their jobs in the risk areas using only 25 percent of the vehicles, assuming an average of four workers per car pool. By selecting sedans and station wagons, average pools of five workers would be possible. Thus, even if only one essential worker in

every five relocated by auto, there would still be enough autos to provide commuting service for the carless. Since essential workers would be assigned to the nearest hosting areas, sufficient fuel should remain for the initial commuting trip to the risk area. The main sources of motor fuel are in the risk areas where commuting vehicles should be refueled routinely.

The principal drawback to carpool commuting was found to be the limited highway capacity. We assumed that key facilities would be on a two-shift operating basis, so that only half the work force would be commuting in one direction in a given time period. Nonetheless, at 5 passengers per auto, a limited-access freeway lane can handle only 7,500 workers per hour and other highways correspondingly less. Thus, a shift commute typically was found to require a five-to-eight-hour period at full capacity. As a consequence, the working hours at the various key facilities would need to be staggered and the commuting operation scheduled very carefully. On the other hand, large buses carrying 50 commuters each can move 18,750 people per hour over a freeway lane or 2 1/2 times as many as by carpool. Accordingly, a shift commute would load the highways for a period of two to three hours, much like normal urban commuting patterns. In most cases, buses used to relocate those without automobiles could be mobilized in the host areas for the commuting operation. In no planning area, however, are there enough large buses (see Table 13) to accommodate a work shift consisting of 4 percent of the risk population, even if a somewhat higher capacity is assumed than in the relocation operation because of lack of encumbering baggage. Small buses would also need to be used and buses delivering a work shift would need to return the off-duty shift. Otherwise, a mix of bus and carpool commuting can be foreseen, with commuter rail of possible consequence in the New York and Philadelphia areas.

Transportation of Essential Supplies

Detailed planning studies will very likely show that pipelines can be used to deliver fuel to some host areas and that railroads can be used to deliver fuel, food, and other essentials in many cases. However, in this analysis, only the use of tractor-truck and trailer combinations for delivery of supplies has been examined. A tractor-truck and trailer can be assumed to deliver about 40,000 pounds of food and other supplies or 7,000 gallons of fuel in each load. Vehicle speeds are assumed to be 40 mph in each direction. Loading and unloading times are assumed to be one hour each.

Resupply of essential materials to satisfy daily consumption appears not to pose a severe problem. Food consumption is about 4 pounds per person per day. Fuel consumption will vary greatly depending on the time of the year, weather, and the quality of housing. For trial calculations, it was assumed that fuel consumption in the host counties will be one gallon per person per day. About 2.43 truckloads per day are needed to supply 10,000 people: 1.0 for food and 1.43 for fuel. If a vehicle is operated 10 hours per day, it can make a round trip each day at a range of 160 miles; at 12 hours, the range is 200 miles. Each vehicle provides the needs of about 4,100 people. In the United States, there is one tractor truck and several trailers for each 200 people, on the average. Therefore, vehicles for supply service appear to be available in abundance. Vehicles not needed to maintain daily deliveries for current consumption can be used to build up reserves and accumulate fuel inventories for the return operation and to supply key risk-area facilities and maintain essential economic activities.

Road capacity appears unlikely to be taxed significantly by resupply services. Fuel needed for resupply vehicles can be drawn from the risk area where inventories should be ample.

Fallout Analysis

To a great extent, the credibility of crisis relocation plans in the Northeast Corridor will hinge on the question of whether it will be feasible to protect both the relocated risk-area populations and the host resident population from fallout, in the event the crisis escalates to nuclear attack. The effectiveness of crisis relocation as well as its credibility is bound up in this question. Therefore, the third aspect of the feasibility study is concerned with an analysis of the fallout threat posed by the attacks underlying the DCPA risk calculations and an examination of the feasibility of various options for providing sufficient and adequate fallout shelter space. The fallout analysis was conducted concurrently with the work on allocation and transportation so that it could be reflected ultimately in our evaluation of the results. The same initial assumptions and ground rules were used.

The postulated attack effects that were used in this study actually represent three different attack conditions. First, the weapons were assumed to be air burst to maximize the areas at risk from direct effects. Then, the weapons were assumed to be ground burst and probable fallout patterns were calculated separately for attacks occurring in the winter and in summer. The computer printout provided by DCPA as an input to the analysis gives only a single value for the probable fallout dose in each county. This value is either the summer dose or the winter dose, whichever is higher. As a result, the attack effects listed in the computer printout and depicted in DCPA TR-82 may be regarded as the worst-worst case--maximum direct effects and maximum fallout during either winter or summer. In reality, the combination of worst-worst cases could not occur. Nonetheless, these risk calculations were used as the starting point for the analysis of feasibility.

Review of Allocation Rules

The initial allocation rules for defining the population at risk and suitable host areas will be recalled as:

Blast Risk

50-50 chance of:

greater than 2 psi . . .	relocate population to places where there is at least a 50-50 chance that the dose will be less than 10,000 R.
less than 2 psi	do not relocate population unless residence is within an urbanized area, then relocate as above.

Fallout Risk

50-50 chance that dose will be:

greater than 10,000 R .	do not use as host area
less than 10,000 R . . .	use to host relocated risk-area population.

With respect to fallout risk, the specified dose is the four-day integrated unprotected exposure at the centroid of the county population. The four-day dose is a common approximation of the maximum equivalent residual dose (ERD) used for casualty estimation.

Significance of Seasonal Winds

DCPA TR-82 [3] identifies 69 counties in the study area having part or all of the county outside the 2 psi contour and having a 50-50 chance of experiencing an unprotected dose of greater than 10,000 R at the population centroid.

These counties or portions thereof are colored green in TR-82. Approximately 1.7 million people reside in these high fallout risk areas. Also, no portion of these counties can be used for hosting.

Since the high-risk areas from fallout can result from the use of either summer or winter wind statistics, an early step in the fallout analysis was to examine whether one or the other of these seasons was dominant in defining the risk. A printout of the fallout data in the ADAGIO source deck obtained from the Institute for Defense Analyses was produced that showed the winter and summer doses at county centroids for various probabilities of occurrence. Comparison of these calculations indicates that in 63 of the 69 fallout-risk counties, the dose at the 50 percent probability level is greater in the summer than in the winter. The data for the six counties that are exceptions to the general rule are presented below:

	50% Probability Dose		
County	Winter	Summer	Population Affected
Cecil County, MD	10,277 R	8,052 R	53,291
Dukes County, MA	10,770	456	6,117
Washington Co., RI	11,294	8,453	47,659
Westmoreland Co., PA	12,544	7,919	100,046
Newport County, RI	16,476	6,828	2,054
Suffolk County, NY	23,018	13,748	63,898

The county at highest risk, Suffolk County, would be off-limits for hosting, winter or summer. In the other five counties, there is a better than 50-50 chance that the dose will be less than 10,000 R during the summer. These five counties have a population of about 209,000 people. At a 5 to 1 hosting ratio, about 1 million people

people from the blast-risk areas could be allocated to these areas under other ground rules that will be evaluated in the next section. Because the summer winds generally result in the worst fallout situation to be planned for in the Northeast Corridor, we used the summer wind statistics for the feasibility analysis.

Fallout Risk--Before and After Relocation

One of the factors that may constrain the feasibility and credibility of crisis relocation plans is whether or not the relocated population would be placed in host areas of relatively lower fallout risk as well as blast risk as the result of the relocation movement. If relocatees were to encounter increased fallout risks as well as a paucity of good fallout shelter in the host areas, one might question whether relocation from at least the low overpressure regions was a sound idea.

The analysis is based on summer wind statistics and the probable dose at the centroid of each county, as listed in the ADAGIO source data. The six initial planning areas (Figure 4) were assumed. Since the analysis was done in advance of results of the allocation procedure, the blast-risk population was assigned in proportion to the host population within each planning area and all potential host counties were used. This meant that the hosting ratio varied among the planning areas, being about 5 in Planning Areas A and B, and less in the other planning areas. The results for each planning area are given in Table 14. An overall summary in the same format is given below:

Table 14

FALLOUT RISK BEFORE AND AFTER RELOCATION

(distributing risk area population uniformly among all potential host counties in each Planning Area)

PLANNING AREA – A	Population Distribution			
	Before Relocation		After Relocation	
	000's	%	000's	%
Counties where there is 50–50 chance that dose will be:				
> 20,000 R	2,698	22.	120	1.0
> 15,000 R	6,592	54.	347	3.5
> 10,000 R	8,019	66.	549	4.5
> 7,000 R	8,886	73.	1,571	13.
> 4,000 R	10,172	84.	3,430	28.
> 2,000 R	11,055	91.	6,907	57.
< 2,000 R	1,106	9.	5,254	43.
PLANNING AREA – B				
> 20,000 R	10,412	58.	48	0.3
> 15,000 R	10,812	60.	52	0.3
> 10,000 R	11,523	64.	116	0.6
> 7,000 R	11,995	67.	116	0.6
> 4,000 R	12,716	71.	818	4.5
> 2,000 R	16,272	91.	8,260	46.
< 2,000 R	1,661	9.	9,672	54.
PLANNING AREA – C				
> 20,000 R	4,622	25.	81	0.4
> 15,000 R	6,114	33.	295	1.6
> 10,000 R	11,559	64.	581	3.2
> 7,000 R	13,432	74.	2,566	14.
> 4,000 R	15,755	87.	8,316	46.
> 2,000 R	17,194	95.	12,976	29.
< 2,000 R	990	5.	5,208	29.

PLANNING AREA – D	Population Distribution			
	Before Relocation		After Relocation	
	000's	%	000's	%
Counties where there is 50–50 chance that dose will be:				
> 20,000 R	–	–	–	–
> 15,000 R	360	0.9	73	1.8
> 10,000 R	2,693	67.	258	6.4
> 7,000 R	3,189	79.	1,607	40.
> 4,000 R	3,469	87.	2,348	58.
> 2,000 R	3,746	94.	2,884	72.
< 2,000 R	255	6.	1,118	28.
PLANNING AREA – E				
> 20,000 R	–	–	–	–
> 15,000 R	1,432	22.	4	.06
> 10,000 R	2,706	41.	9	.1
> 7,000 R	2,879	44.	369	5.6
> 4,000 R	2,983	45.	556	8.4
> 2,000 R	4,689	71.	1,119	17.
< 2,000 R	1,898	29.	5,468	83.
PLANNING AREA – F				
> 20,000 R	–	–	–	–
> 15,000 R	–	–	–	–
> 10,000 R	–	–	–	–
> 7,000 R	–	–	–	–
> 4,000 R	40	2.4	13	0.8
> 2,000 R	509	32.	149	9.2
< 2,000 R	1,104	68.	1,464	90.7

Population at Risk from Fallout

Counties where there is a 50-50 chance dose will be:	Before Relocation (000's)		After Relocation (000's)	
Greater than 20,000 R	12,736	(21%)	241	(0.4%)
Greater than 15,000 R	24,910	(41%)	771	(1.2%)
Greater than 10,000 R	36,500	(61%)	1,513	(2.5%)
Greater than 7,000 R	40,381	(66%)	6,229	(10%)
Greater than 4,000 R	45,135	(75%)	15,478	(26%)
Greater than 2,000 R	53,465	(87%)	32,295	(53%)
Less than 2,000 R	7,014	(13%)	28,184	(47%)

In general and in each of the planning areas, relocating the blast-risk population substantially reduces the numbers of people exposed to a given level of fallout risk. This is to be expected not only because no people are relocated to counties with a probable dose over 10,000 R but also because, in the study area, the main attacks are along the Northeast Corridor where the blast-risk population is being relocated inland and generally upwind of the principal sources of fallout. For these reasons, we believe that neither revisions in the boundaries of the planning areas nor the use of a uniform 5 to 1 hosting ratio in the allocation of risk populations would alter the generalizations to be drawn from Table 14.

Fallout Shelter Requirements

The general rule for providing fallout shelter should be to strive for the highest protection factors that are achievable through the use of the best existing shelter, shelter upgrading, and construction of expedient shelter. The feasibility of providing adequate and sufficient fallout shelter will depend on:

- the fallout risk in the host county
- the allocation of relocatees to the county

- the availability of existing and upgradable shelter facilities in the host county

- the availability of suitable earthmoving equipment.

Of the above factors, only the allocation of people is subject to substantial manipulation by CRP planners.

In considering the significance of the estimates of probable doses to the matter of the provision of fallout shelter, some convenient measure of adequacy must be adopted. For this study, we have chosen to adopt the criterion of limiting the exposure in shelter to 100 R, a dose that is at or near the onset of radiation sickness symptoms. That is, while advocating that the more fallout protection the better is the general rule, that which is available or which can be produced is considered adequate if it offers a 50-50 chance of restricting the sheltered dose to less than 100 R. This criterion appears to be consistent with the DCPA risk criteria since the defined areas of high fallout risk (greater than 10,000 R unprotected) would require shelters with a protection factor greater than 100 according to the criterion.

For a number of cogent reasons, the fallout protection afforded by shelter in existing structures is usually recorded and reported in terms of ranges of protection factors, called protection categories. Those in use by DCPA are as follows:

Category	Protection Factor Range
1	20 to 39
2	40 to 69
3	70 to 99
4	100 to 149
5	150 to 249
6	250 to 499
7	500 to 1000
8	Over 1000

Obviously, the average protection factor afforded by shelter of a given category is greater than the lower bound of the range. In this study, however, we will assume that the protection afforded is the lowest in the range. This practice is conservative; thus, the chance of limiting the exposure to less than 100 R would be better than 50-50.

On this basis, then, the population in counties with a probable dose of less than 2,000 R in the summary table and in Table 14 would be protected adequately by Category 1 shelter. For the study area as a whole, 47 percent of the population can be served by such shelter in the relocated mode. Category 2 shelter would be adequate in counties having a probable dose between 2,000 and 4,000 R. According to the summary table, 74 percent of the population after relocation would be adequately protected by Category 2 shelter. Similarly, 16 percent would need at least Category 3 shelter; 7.5 percent, Category 4 shelter; and 2.5 percent, Category 5 or better.

Fallout Shelter Availability

These results, which should be applicable as well to the actual allocations performed in the feasibility analysis, can now be compared to the availability of fallout shelter in the study area. The major program for identifying fallout shelters over the past fourteen years has been the National Shelter Survey (NSS). Through this survey, over 226 million 10-square-foot shelter spaces with a protection factor of 40 or more (Category 2+) have been identified in existing structures as of 30 June 1975.[13] Most of the spaces identified, however, are located in the risk areas. It is known that earlier surveys of nonurban counties were incomplete. The few potential host counties that have been surveyed in DCPA's "host area survey" have tended to identify two to three times as much shelter in existing structures as had been documented previously. Rural counties have been deficit counties, of course, so the more recent surveys have only tended to make the host areas more self-sufficient with respect to protecting

their resident population. The situation tends to vary considerably among the counties surveyed. In 1974, for which survey data are readily available, host counties in the vicinity of three risk areas in the Northeast Corridor study area exhibited the following shelter resources:

Resource	Risk Area Vicinity		
	Springfield, MA	Utica-Rome, NY	Dover, DE
Existing Cat 1+ space Percent of Res. Req.	436,555 435%	203,403 184%	67,521 84%
Space upgradable to Category 1+	379,720	115,566	173,378
Existing plus upgradable Percent of Res. Req.	816,175 814%	318,969 288%	240,899 300%

Thus, there exists or can easily be produced sufficient Category 1 or better shelter not only for the residential population in these sample host counties but also sufficient to serve 7 relocatees for each host in the Springfield area and about 2 relocatees per host in the other areas. The data are too sparse to indicate whether these results are sufficiently typical to meet the needs of the average 5 to 1 hosting ratio used in this feasibility study although the data for the areas surveyed would satisfy a hosting ratio of 4.72. But these data are confined to nonresidential, nonfarm structures. Over 89 percent of residences in DCPA Region 1 have basements and most of these have Category 1+ shelter in at least the corners of the basements without any upgrading. This resource should cover at least the residential population, leaving the shelter shown in the table above for the use of relocatees. With any degree of basement sharing, there is ample shelter in prospect--if the anticipated fallout exposure is not too severe. According to our analysis, this optimistic picture applies only to about half the population of the study area. The other half will require Category 2 or better shelter for adequate protection, much of it of very high quality.

It may be noted, for example, that in the Springfield, Massachusetts, host counties a high proportion of Category 1 or better space was found. But the probable dose in these same counties ranges from about 7,500 R to over 8,600 R. Only Category 4+ shelter would be adequate according to our criteria. The same holds true in the Dover, Delaware host area, where the probable dose is estimated to be about 9,400 R. Only in the Utica-Rome, New York, hosting area are doses projected to be less than 4,000 R unprotected.

A recent study by York et al. of the Research Triangle Institute[14] offers some useful insights into the sheltering problem in crisis relocation. For much of its presentation, the RTI study uses DCPA Region 1 as an example. Thus, their data include our Planning Areas A and B and the New Jersey portion of Planning Area C. The fallout protection situation in DCPA Region 1 is perhaps representative of the Northeast Corridor except for Virginia and West Virginia, in which the probable doses are much lower.

York et al. present calculations having to do with alternative ways of providing host area fallout protection. Their objectives do not concern the adequacy of the protection afforded by the various alternatives analyzed but sufficient data are included to permit us to draw our own conclusions in this respect. As resources available within Region 1 for sheltering, the RTI study offers the estimates shown in Table 15. It will be noted that no existing space is credited to NSS shelters, on the basis that most of the space is found in the risk areas and the allocation of people to particular host counties was unknown. Only the space in mines, caves, and tunnels is drawn from the NSS inventory. Data from the 1974 host area pilot survey results would suggest that there are perhaps 12 million existing shelter spaces in NSS structures in Region 1, of which only 640,000 are included in Table 15.

Table 15

AVAILABILITIES OF RESOURCES IN REGION 1[1]

Shelter Resource	Availability
Spaces in existing facilities:	
Mines	383,876
Caves	6,275
Tunnels	250,000
Other NSS	Unknown
Private homes with basements	36,254,269
Small nonresidential buildings	7,125,000
Small nonresidential buildings with basements	375,000
Other resources essential to shelter construction and utilization:	
Planning (dollars)	2,000,000
Identification (dollars)	4,500,000
Heavy equipment (cubic yards/hour)	7,838,173
Manpower (man-hours)	382,956,490
Axes	9,756,000
Saws	20,772,000
Picks	8,496,000
Shovels	15,876,000
Hammers	19,044,000
2" Lumber (board feet)	581,589,760
4" Lumber (board feet)	14,662,434
Plywood (square feet)	180,531,750
Polyethylene (square feet)	2,781,910,800
Green poles (board feet)	7,000,000,000

[1] Based on Table 5 of S.B. York III et al., Alternative Ways of Providing Host Area Fallout Protection, Research Triangle Institute (December 1975).

The RTI study[14] employs a linear programming analysis to determine the best combination of shelter types from the point of view of the most efficient use of the resources exhibited in Table 15. Since they do not consider the protection factor requirement, their basic result for DCPA Region 1 uses all of the mines, caves, and tunnels to meet about 2 percent of the shelter requirement, upgrades the small nonresidential buildings with basements to meet another 1 percent of the need, and satisfies 97 percent of the need by upgrading the protection afforded by residential basements. The drawdown on other resources is quite nominal: about 30 to 70 percent of the available heavy equipment, depending on whether the soil is light or heavy, about 18 percent of the manpower available, about half the hand tools, 14 percent of available 2" lumber, and about a third of the available polyethylene. The drawdown on equipment and manpower is based on completing the shelter upgrading job in a period of 48 hours.

The earthmoving requirements are calculated for a cover of one foot on the roof or second floor of buildings without basements and on the ground floor of buildings with basements. In addition, earth is piled up against the sides of the building to a height of six feet. It is stated in the reference that this should provide a protection of 40 PF or more (Category 2 shelter). Although some DCPA experiments suggest that these kinds of structures might be upgraded to a higher category, it would seem that for practical purposes upgrading of existing structures will produce Category 3+ shelter only rarely. Hence, throughout the host areas of the Northeast Corridor, fallout protection for about three-quarters of the population (those in areas where the probable dose is 4,000 R or less) can be provided by upgrading existing buildings. For the other 25 percent, this approach does not offer adequate fallout protection according to our criteria.

To obtain higher protection factors, the RTI study relies on the expedient shelters described in the <u>Expedient Shelter Handbook</u> by

Christie and Kearney of the Oak Ridge National Laboratory.[15] These generally provide a protection factor of 1,000 or better (Category 8) and thus are useful to provide adequate shelter anywhere in the Northeast Corridor. Several tables in the reference (specifically, Tables 9 and 10) apply to conditions under which the upgrading of existing buildings is minimized. From 82 to 89 percent of the shelter requirement is met by construction of expedient shelters of the following types (in order of use): door-covered trench, catenary wire-roofed trench, aboveground 60-person A-frame, and semiburied 60-person A-frame. The remainder of the requirement can be met in general by use of mines, caves, and tunnels, and the very best of the NSS shelters. The construction of expedient shelter stresses the available resources in DCPA Region 1 (Table 15), using all of the heavy equipment capacity, all of the plywood, most or all of the shovels, 90 percent of the 2" lumber available, and up to 80 percent of the polyethylene sheeting. About half the available manpower is needed. Costs appear to be about double those associated with the upgrading of existing buildings. Thus, the providing of adequate fallout shelter in the Northeast Corridor appears to be feasible within the limits of indigenous resources but the shelter upgrading approach, which offers a number of advantages in terms of time, cost, and habitability, appears applicable to only about three-quarters of the study-area population. Expedient shelter construction would be required for the remainder.

Summary

In this section, we have investigated the basic feasibility of crisis relocation in the Northeast Corridor from three points of view:

- Whether the risk population could be hosted within reasonable travel distances of the cities
- Whether the transportation resources available could permit the exodus from the cities to be completed within a three-day period, including the transport of those without private vehicles, and whether commuting to and from the risk areas was feasible

- Whether adequate fallout protection could be made available in the host areas, should a nuclear attack on the cities ensue.

Our conclusions at this point would indicate marginal feasibility at best. A reasonable allocation of risk populations to potential host counties seems feasible if average highway distances of nearly 200 miles and a maximum relocation distance of nearly 320 miles are considered satisfactory and if commuting distances (one-way) of 100 miles or more are judged feasible. Transportation resources seem generally adequate except for the highway net in the vicinity of the largest conurbations. If highways are utilized in the normal manner, the exodus in the Boston, New York, and Philadelphia areas will take considerably more than three days; that in New York at least a week. The commuting situation in the New York and Philadelphia areas is not satisfactory, involving excessive one-way commuting times. The fallout situation that might occur if an attack of surface bursts eventuated can be dealt with by crisis shelter preparations. Fully 25 percent of the population would require expedient shelters with high fallout protection. The remainder could be protected by shelter upgrading techniques. Existing shelter in the prospective host areas is marginal in quantity for the resident population and is inadequate in quality in many places. This basic shelter situation, of course, has nothing to do with crisis relocation. It is a fact whether or not relocation is planned for.

During the course of research that led to the results described in this section, a considerable number of alternatives suggested themselves that might alleviate the conditions restricting crisis relocation in various ways. Therefore, we engaged in a continual evaluation of the results as they became apparent and investigated how they might be altered for the better. The results of this effort are described in the next section.

III EVALUATION

In this section, we propose to discuss what appear to be the critical aspects of the analysis described in the previous section. Some of these aspects are supportive of the position that crisis relocation planning for the Northeast Corridor is feasible. Some of them represent major constraints and difficulties exposed by the analysis. Other aspects have to do with procedures and assumptions that are susceptible to some modification and improvement. In most instances, we have explored alternatives and made sensitivity studies as an aid in evaluating the outcome. The results are reflected in the "preferred solution" exhibited in Section IV and in the planning guidance under preparation.

It should be noted at the outset that the variations and adjustments discussed here are considered to be within the spirit of the assumptions and policies that have guided the evolution of crisis relocation planning concepts. For that reason, the revision described in the next section is stated to be within existing policies and guidance. More radical approaches to crisis evacuation in the study area are raised in Section V for consideration.

Planning Areas

We divided the study area (DCPA Regions 1 and 2) into a series of planning areas partly because we were forced by necessity to develop a hand method of allocating the risk population to host counties in an equitable way and partly because the geographic relationship of the major conurbations and the roads leading from them dictated a rather natural partitioning of the area. On the whole, the planning areas arrived at (Figure 5) seem reasonable and about the best one can do. It would have been to some advantage to have

made the planning areas follow State lines entirely to ease jurisdictional and coordination problems, were the scheme to be deployed. This could be accomplished in Planning Areas A, B, and C at the cost of increasing the hosting ratio to six, at least in New England, but the Washington metropolitan area is essentially interstate in nature and Baltimore-Wilmington would require a high hosting ratio if confined within the two States of Delaware and Maryland. From the transportation point of view, the New York planning area causes the most concern because of the need for so many people to traverse the Hudson River valley. But with New Jersey and much of Connecticut denied to hosting because of the fallout risk, there is little else to do about New York City short of a more detailed analysis of that area than could be accomplished within this study.

One weakness of the current planning areas is that several of them contain more than one "relocation flow" system. For example, the allocation problem in Planning Area C is really two separable allocations: the movement of the Northeast New Jersey conurbation into northern Pennsylvania and the movement of Philadelphia and the rest of New Jersey into southern Pennsylvania. In the feasibility analysis, we chose the latter as representative of the critical planning problem and did not look closely at the northern situation. Similarly, there is an eastern New England flow centered on Rhode Island and Boston and a quite separable allocation problem to the west involving most of Connecticut and the western Massachusetts risk areas. In Virginia, there are really three planning areas: the flow of the Washington area south, the flow of the tidewater risk area westward, and the remaining risk areas in the southwest part. In our final analysis, we have subdivided these planning areas accordingly.

Allocation Procedure

We experimented with several procedural alternatives in performing the allocation of risk populations to hosting space during the

feasibility analysis. Our governing objective was to equalize to the greatest extent possible the travel distances among the various risk areas. This led us to begin each allocation with the largest risk area or the largest along the seaboard that was already remote from much of the hosting area. To keep relocation travel equitable, inland risk areas were not allocated space until the allocation from the seaboard cities had reached them and engulfed them. Accordingly, these inland risk areas were assigned hosting space in the direction away from the seaboard communities. The procedure, as it was refined, easily led to the concept of a "relocation flow." For example, in eastern New England the flow was from south to north beginning with the New London area and picking up the Rhode Island and eastern Massachusetts risk areas as it proceeded past Boston and into New Hampshire and Maine. The concept of a relocation flow has proved quite useful in the preparation of the allocation guidance and is probably generally applicable throughout the country.

For planning purposes, we chose to consider the employees and their dependents of key organizations as comprising 20 percent of the risk-area population. This "slice" had to be allocated the nearest available hosting space in the relocation flow for commuting feasibility. After experimenting with other approaches, we finally settled on the 20 percent slice method for the entire allocation--that is, the risk area most remote from the host area (Suffolk County on Long Island in Planning Area B, for example) would be allocated space for 20 percent of its risk population either in its own nonrisk part, if it existed, or in the nearest host county or counties. Then, the next most remote risk county (Nassau County on Long Island in Planning Area B, for example) would get its turn and so on. In the New York example, the cycle would terminate with Rockland County in the New York area because the next risk area, Albany, had not yet been "engulfed" by the allocation process. Hence, the allocation would return to Suffolk County and assign a second 20 percent slice and so on. Eventually, the first 20 percent slice for Albany County would get its turn when

assignments were being made north and west of Albany. This procedure is being described in the guidance material and was used in the allocation given in Section IV.

The Hosting Ratio

For this study, we have selected a hosting ratio of five relocatees for each host-county resident. As discussed in the previous section, this is equivalent to the allocation of 20 square feet of usable floor area in congregate-care facilities in a county of average hosting resources. A hosting ratio of 6 to 1 would imply an allocation of 16 2/3 square feet per person, since survey data suggest that there is about 100 square feet of congregate-care space per host on the average. The effect of using a higher hosting ratio on relocation distances is shown in Table 16. The use of a 6 to 1 ratio in Planning Areas B and C has the effect of reducing the average travel distance by 20 to 30 miles and the maximum travel distance by 30 to 65 miles. It is difficult, in our opinion, to make a judgment as to whether the reduction in travel distance is worth the increased crowding entailed by the higher hosting ratio. Until more experience has been gained in the utilization of nonresidential structures for housing, we would suggest that the lower hosting ratio is preferable.

The use of a hosting ratio or, alternatively, a housing space allocation based on the average per capita congregate-care space found in past surveys is undoubtedly adequate for testing the feasibility of crisis relocation. We foresee, however, a practical difficulty in the deployment of CRP in areas of high population density. As noted in the previous section, the actual availability of congregate-care space can deviate significantly from the average. In the 1974 host area survey, for example, the raw average number of 40-square-foot spaces was about 4 per capita but the availability county-by-county ranged from less than 2 to over 8 spaces per capita. Thus, our allocations, being based on average numbers, are not useful for

Table 16

EFFECT OF HOSTING RATIO ON RELOCATION DISTANCE

AREA	METRO	5:1 HOSTING RATIO		6:1 HOSTING RATIO	
		Average Dist.	Maximum Dist.	Average Dist.	Maximum Dist.
B	New York City	188	319	169	290
C	Philadelphia	133	262	103	197

actual planning. They would need to be modified in vitually every detail when existing hosting capacity was known and used.

That the hosting capacity problem is far from trivial can be shown by the following example. Oneida County, New York, which contains the Utica-Rome risk area, had a 1970 census population of about 273,000 people, of whom about 219,000 resided in the risk area and 54,000 in the nonrisk area. At an average hosting ratio of 5, there is ostensibly space for 270,000 relocatees in the nonrisk part of the county, enough for the risk population and 51,000 people from the New York area. Oneida County is, however, one of the counties in which a survey was made in 1974 of the congregate-care space available in the nonrisk portion. The survey indicates space for only 104,000 people at the space allocation dictated by a hosting ratio of 5 to 1. This is less than half the number needed for the risk population of the county. Thus, while our allocation would leave the Utica-Rome risk population within the county, actually over half would need to be assigned to western New York State.

Similarly, some host counties will have hosting capacity for many more than the average number assigned in our allocation. As an example, the survey done in Franklin County, Massachusetts, would indicate that about 9 relocatees should be assigned for every resident rather than the 5 to 1 ratio we used throughout the allocation. A review of this situation indicates that either the actual housing capacity should be available prior to allocation in each planning area or else the allocation should be based on a prediction of housing capacity that is accurate to within plus or minus 20 percent. Otherwise, DCPA would be faced with a major revision in the allocation when the housing capacities became known. Since making host area surveys throughout all areas of high population density will take considerable time and effort, especially if conducted more or less as has been done, the development of a reasonably reliable predictive method should be given high priority.

In view of the sensitivity of a detailed allocation to assumptions on county hosting capacity, a small effort was made during this study in an attempt to improve on the "per capita" estimates made in prior work.[20] The results of a "four-element method" are given in Appendix 1. While some improvement in predictive capability was achieved, the results are not sufficiently accurate to warrant their use. Hence, a common hosting ratio of five has been retained in this feasibility analysis.

Definition of Blast Risk

The current definition of blast risk used by DCPA is an either-or proposition. A population element is considered to be at blast risk either if its centroid has a 50-50 chance of being subjected to at least 2 psi blast overpressure or if the area (not necessarily a whole political subdivision) is included in an urbanized area. The underlying concepts for this definition seem quite reasonable in the abstract. As we worked with the definition, however, we became aware of a practical problem.

Conceptually, the population can be regarded either as a target in its own right or as merely colocated with important military or industrial targets. In the latter case, the risk of blast overpressure from attacks on the other targets is a reasonable criterion for crisis relocation. As a target in its own right, on the other hand, one should be concerned with the degree of population concentration. The urbanized area, as defined by the Bureau of the Census, has been used for the latter criterion since it is generally a central city of 50,000 or more inhabitants, together with the surrounding closely settled territory having a population density of 1,000 inhabitants or more per square mile. Originally, urbanized areas were intended to be compact, with small areas of lower population density sometimes included to eliminate enclaves and to close indentations in the main population body. More recently, however, the Census has been allowing "tentacles" of urbanization to accrete on the main urbanized body, especially in the large metropolitan areas. This process not

only tends to degrade the targeting concept but also creates a planning situation that is virtually impossible to make credible to the public.

A prime example of the blast-risk definitional problem is the New York-Northeast New Jersey urbanized area shown in Figure 7. The hatched and stippled areas on this map are parts of the urbanized area. The white areas are not. Note the tentacle going up either side of the Hudson River above the edge of the blast-risk area. This tentacle crosses upper Westchester County and terminates in Putnam County beyond the cordon line selected for evaluation of highway capacities. Another tentacle in the same vicinity juts out to the northeast. Two points should be made about these tentacles. First, these strips of minor urbanization are not suitable targets in their own right. Second, they do not correspond to political boundaries and would be almost impossible to describe in any emergency instructions to the public about crisis relocation. Indeed, it would not be credible to tell the residents of the white area between these tentacles to stay put and at the same time send the households in the marked areas to relocation sites hundreds of miles to the north. For practical purposes, one must plan to evacuate all of Westchester County or else choose an easily identified boundary in the immediate vicinity of the area of blast risk (and the main body of urbanization.)

As we have seen in Section II, the highway system in the New York area is likely to be strained beyond capacity. If those living in Westchester and Rockland Counties above the blast-risk area were excluded from relocation, about 135,000 people would not have to move across the key cordon. A similar situation exists in other counties on the map and in other urbanized areas. (Note, for example, the tentacles in northwestern New Jersey and along the New Jersey coast.) We concluded that, in general, tentacles of urbanization beyond the main body not subject to blast overpressure for other reasons should be excluded from the definition of blast risk for crisis relocation purposes. As will be seen in the next section, the feasibility of relocation in the large cities of the Northeast Corridor is materially improved by this practice.

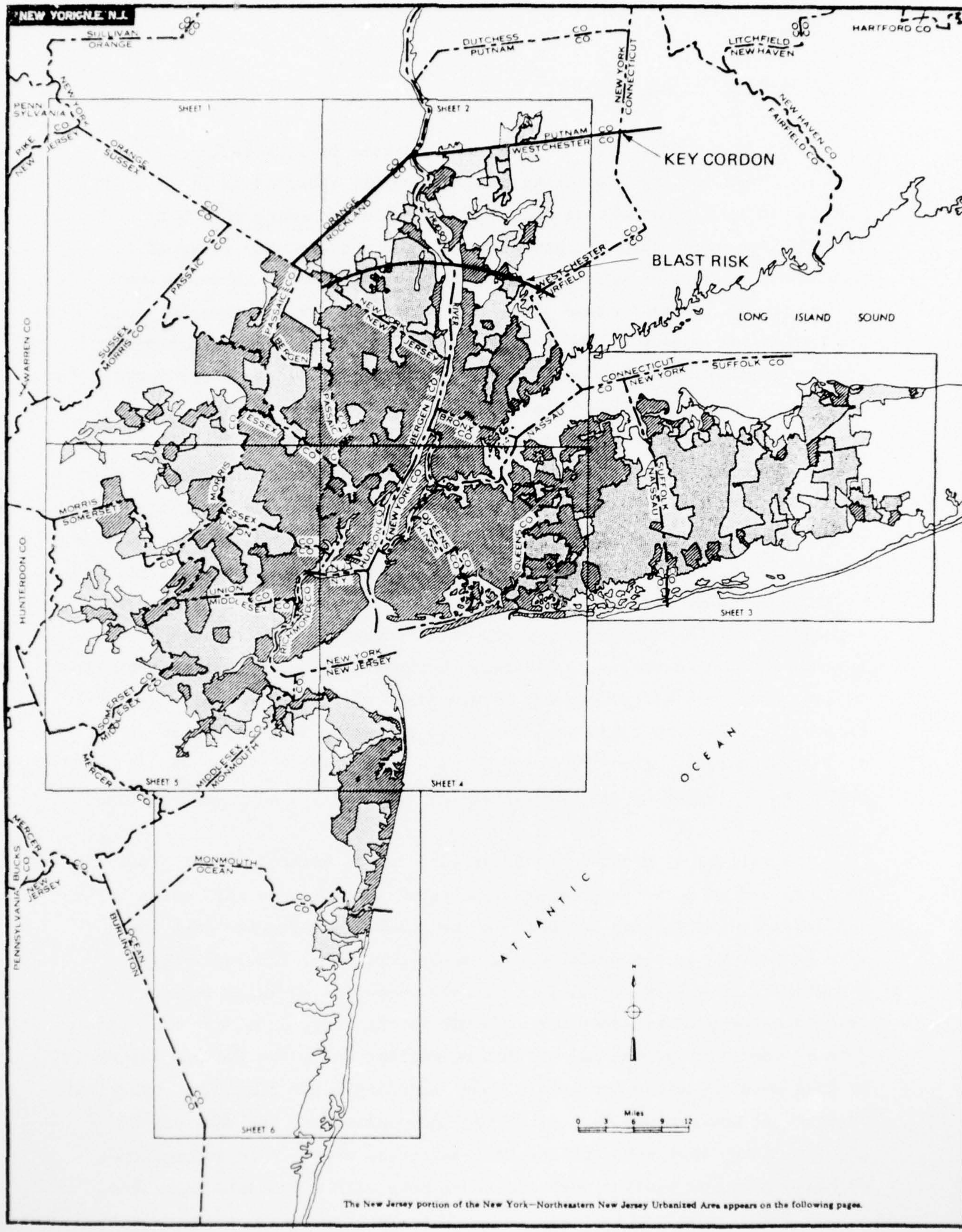

Figure 7 URBANIZATION IN THE NEW YORK AREA

Definition of Fallout Risk

The current definition of fallout risk used by DCPA excludes counties from hosting relocatees when the county centroid is so located that there is a 50-50 chance of a four-day dose exceeding 10,000 R. In many instances along the Northeast Corridor, the county centroid is within the blast-risk area or is otherwise located so as to cause the entire county to be assessed at fallout risk. In other works, fallout risk is assessed only at the county centroid in contrast to blast risk, which is assessed at the much smaller MCD (minor civil division) level. In consequence, some county areas that are upwind or crosswind of areas of direct effects are assessed at fallout risk although it is likely that they are not. Although there are only limited areas improperly assessed at fallout risk, these areas are of great importance to the feasibility of crisis relocation. Because of their location adjacent to the blast-risk area, such areas would be used for hosting critical workers and their families. Commuting distances would be reduced, especially in Planning Area C, where it is currently over 100 miles for much of the essential work force. Moreover, most of these potential hosting areas are within our key cordon lines where many urban roads exist. At a hosting ratio of 5 to 1, the reduction in the numbers of risk-area residents crossing the cordons on the rural highways should have a major impact on the feasibility of emptying the very large cities.

The calculated probable dose for each county centroid was plotted on a map and dose contours drawn. The resulting dose contours were not sufficiently precise to indicate the manner in which the dose would vary from place to place within counties. Therefore, the Research Directorate of DCPA was requested to make a special computer run to calculate the probable dose for each MCD in the study area. It was quickly learned that the calculation of fallout doses for various points is much more laborious and costly than assessing blast risk. For practical reasons, it was decided to confine the computations to the MCDs within green counties that were outside the blast-risk area. This assured that we could gain for hosting purposes those MCDs with a probable dose less

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THE FEASIBILITY OF CRISIS RELOCATION IN THE NORTHEAST CORRIDOR.(U)
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than 10,000 R. What was lost was the opportunity to discover MCDs at fallout risk in "white counties" where the probable dose at the county centroid was less than 10,000 R. These MCDs, if they exist, lie downwind of attacks on the smaller risk areas. They are currently used for hosting because the fallout assessment is too coarse to discover them. Overall, the hosting capacity associated with these unknown fallout-risk MCDs is too small to have a significant effect on the question of feasibility of crisis relocation. Nonetheless, crisis relocation plans would be more credible and effective if fallout risk were assessed throughout the country at the MCD level as it is presently done for blast risk.

Separate calculations were made in the green counties for winter wind statistics and summer wind statistics. These calculations confirmed the observation that the fallout risk was greater in the summer than in the winter. If it is also noted that crisis relocation is much more likely to be implemented in the summer than in the winter, then it seems sensible to base relocation plans on the summer wind statistics. We would recommend this practice and have used it in subsequent analyses.

Table 17 lists the data obtained from the special computer run for the summer wind statistics. A total of 161 minor civil divisions located in 25 green counties were found to have probable doses of less than 10,000 R. The average unprotected dose in these MCDs was about 6,400 R. The total population of the MCDs was 669,413, according to the 1970 census. At a hosting ratio of 5 to 1, nearly 3,350,000 people could be hosted in these MCDs, most of which were strategically located. When combined with the elimination of urbanized tentacles from the blast risk definition, the impact on relocation and commuting distances is quite substantial. Table 18 gives a comparison for the planning areas (B and C) having the largest travel distances in the original analysis.

Table 17

SUMMARY OF FALLOUT RISK ASSESSMENT

Green Counties	MCDs<10,000R	Pop. of MCDs<10,000R	Avg. Dose R
Planning Area A			
Hartford CT	1	1,303	2,213
Middlesex CT	1	8,468	8,548
New London CT	1	4,964	8,660
Dukes MA	7	6,017	387
Plymouth MA	2	30,098	7,714
Worcester MA	3	18,629	9,412
Hillsborough NH	21	35,380	6,336
Rockingham NH	4	5,653	8,140
Newport RI	1	2,385	6,119
Washington RI	5	30,028	4,510
Planning Area B			
Rockland NY	2	38,015	7,163
Suffolk NY	4	29,594	1,309
Westchester NY	9	141,373	3,003
Planning Area C			
Cape May NJ	1	3,483	9,949
Morris NJ	7	34,728	5,396
Somerset NJ	6	28,795	7,981
Armstrong PA	20	18,333	8,116
Bucks PA	23	68,236	5,122
Westmoreland PA	24	122,400	2,579
York PA	5	5,912	4,835
Planning Area D			
Baltimore MD	1	3,120	9,559
Cecil MD	5	20,467	8,475
Dorchester MD	3	978	9,740
Planning Area E			
Montgomery	2	4,259	5,715
St. Marys	3	6,795	9,066
Total	161	669,413	Grand Avg. 6,402

Table 18

EFFECT OF RISK CHANGES ON RELOCATION AND COMMUTING DISTANCES

AREA	METROPOLITAN AREA	MAXIMUM RELOCATION DISTANCE (miles)		MAXIMUM COMMUTING DISTANCE (miles)	
		ORIGINAL	REVISED	ORIGINAL	REVISED
B	New York	319	278	94	79
C	Philadelphia	262	233	112	76

Fallout Risk Criteria

In the results of Section II and the foregoing, the probable dose, in which there is a 50-50 chance of not exceeding a stated unprotected dose, has been used. In particular, we adopted a sheltering criterion of keeping the sheltered dose less than 100 R at least 50 percent of the time. This criterion does not indicate adequately the fallout protection factors that should be provided. While 50 percent of the time the dose in a given location will be less than the stated value, it is equally likely to be greater. We recognized this fact in Section II by using the lower bound of protection factors for a category of fallout shelter, thus increasing the probability of a lower dose somewhat. It would seem, however, that shelter protection should be based on the maximum dose that might be encountered. For practical purposes, basing fallout shelter needs on the unprotected dose that would not be exceeded 90 percent of the time would be more representative of the maximum.

Unfortunately, computations of the dose at county centroids at the 90 percent probability level were not available for this study. The ADAGIO source data did include, however, the fallout dose at each county centroid at the 75 percent probability level. When combined with our practice of using the lower bound of the protection category, a result more representative of the maximum can be considered. Table 19 summarizes the effect of this change in the fallout shelter criterion. At the 50 percent level, 47 percent of the 60 million people in the study area can be protected adequately by Category 1 shelter. At the 75 percent level, the proportion falls to 36 percent. At the high-performance end of the spectrum, the proportion requiring Category 4 or better shelter is about doubled by the more stringent standard. Figure 8 maps the counties in the study area in which shelters better than Category 2 would be required at the 75 percent probability level. Shelter upgrading techniques should suffice in the unshaded areas.

Table 19

PERCENT OF POPULATION PROTECTED BY SHELTER CATEGORIES

Probability Level	PF Category 1	PF Category 2	PF Category 3	PF Category 4	PF Category 5,6
50 percent risk	47	27	16	7.5	2.5
(cumulative)	47	74	90	97.5	100
75 percent risk	35	31	13	11	10
(cumulative)	35	66	79	90	100

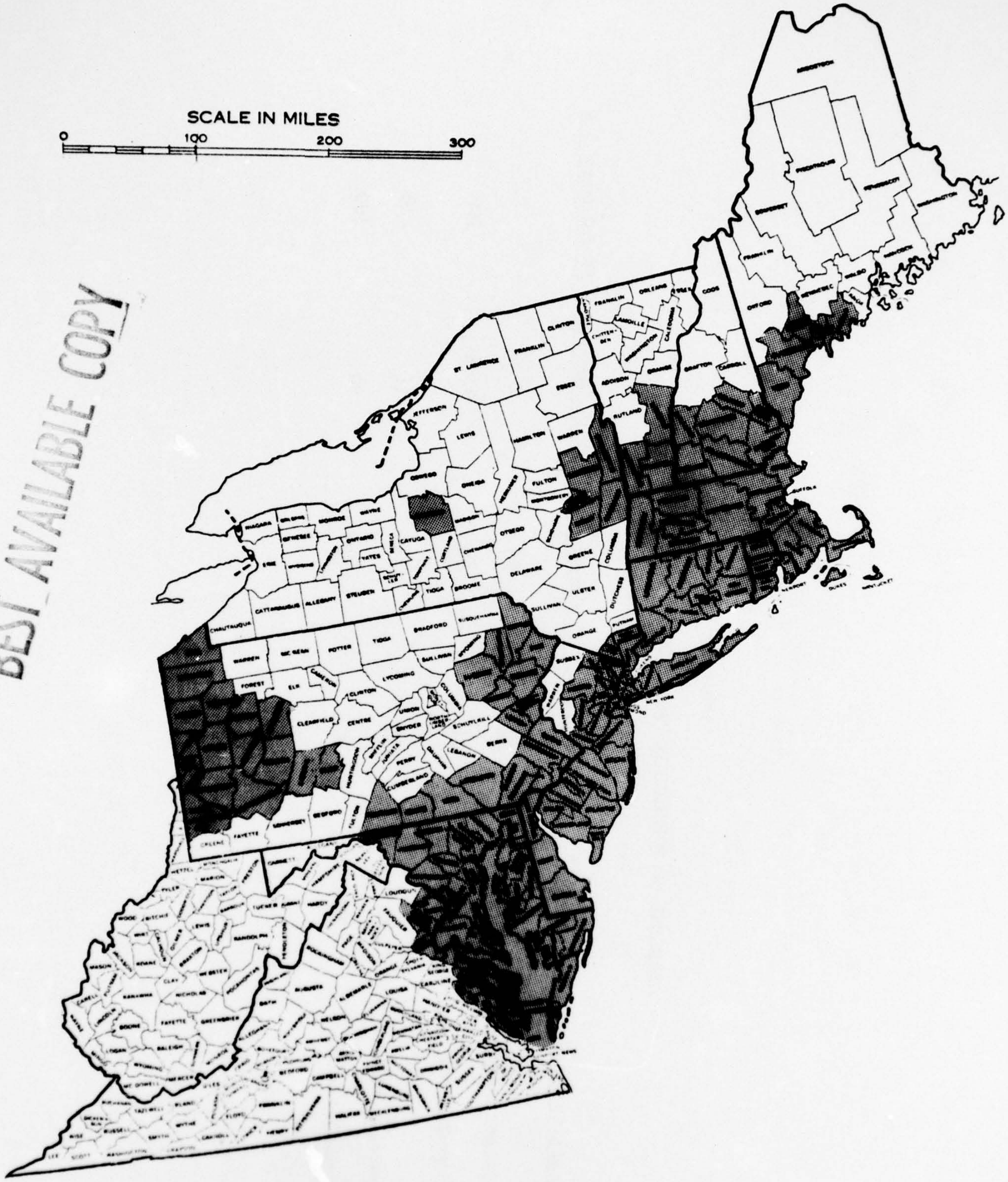


Figure 8 COUNTIES REQUIRING A PF CATEGORY GREATER THAN TWO
(For a 75 percent probability of Less than 100 R)

Another option that might be considered in light of the fallout predictions for the Northeast Corridor would be to change the allocation rules to place more people in the unshaded areas of Figure 8. Several modifications to the allocation rules, which considered the fallout risk in host counties, were examined in the course of this study to estimate how they might influence the feasibility of providing adequate fallout shelter. The first and obvious alternative would be to exclude allocation of the blast-risk population to those counties where there is at least a 50-50 chance of exceeding 7,000 R, or even 4,000 R, rather than the current 10,000 R. The advantage of this alternative is that it would substantially reduce the risk that protection afforded by shelter upgrading would not be adequate. However, if the number of relocatees allocated to a host county is reduced or eliminated because of a substantial fallout risk, it would be necessary to increase the hosting ratio in other host counties or send relocatees greater distances or both.

For this analysis, we used the initial planning areas (Figure 4) and disregarded any restrictions on travel distance within each planning area so that all suitable hosting area might be used. For summer winds at the 50 percent probability level, the following tabulation indicates the changes in average hosting ratios that would result under policies that exclude use of counties for hosting evacuees if there is a 50-50 chance that the dose will exceed the listed value.

	Required Hosting Ratio		
Planning Area	10,000 R	7,000 R	4,000 R
A	4.84	5.32	6.44
B	4.90	4.90	5.10
C	4.34	4.84	7.72
D	3.66	5.72	8.28
E	2.56	2.70	2.79

(Area F was not calculated.)

Lowering the exclusion criterion from 10,000 R to 7,000 R is probably a viable option, since the counties assigned to Area D could be expanded in the west at the expense of Area E (as was done in the revised definition of planning areas). On the other hand, excluding counties with a 50-50 chance of a dose exceeding 4,000 R is probably not a viable option except in Areas B and E, because of the high hosting ratios and travel distances involved.

The alternative of reducing the exclusion criterion from 10,000 R to 7,000 R can also be evaluated by the following comparison with the calculations of Section II:

	Population (1,000s) in Counties Where There is a 50-50 Chance That Dose Will be Greater Than 7,000 R, Requiring Category 3 or Better Shelter	
Planning Area	Initial Allocation	Alternative A
A	1,571	742
B	116	116
C	2,566	953
D	1,607	548
E	369	153
Total	6,229	2,521

Under this alternative, there would be a net reduction of 3.7 million people in places where Category 2 shelter would not be adequate at the 50 percent probability level. However, such a planning policy would place in question the ability to host essential workers and their families through denial of nearby hosting space. A glance at Figure 8 will show that the commuting situation would be impossible for many of the large risk areas.

The second allocation policy that was examined was to use all potential host counties not excluded by the 10,000 R rule but to adjust the hosting ratio (or space allocation) so that fewer relocatees would be allocated to host counties where the fallout risk was above the average.

The potential host counties of each planning area were listed in order of increasing fallout risk (50-50 chance at the county population centroid for summer winds). The list was then divided into three parts, each containing one-third of the potential host population.

The blast-risk population was then allocated to host counties in the following manner:

- One-sixth of the blast-risk population was allocated to the host counties where the fallout risk was highest (the last group in the ordered listing).
- One-half of the blast-risk population was allocated to the host counties where the fallout risk was lowest (the first group in the ordered listing).
- The remaining third of the blast-risk population was allocated to the remaining host counties (the middle group in the list).

The effect of this procedure is to increase the hosting ratio to 1.5 times the average in the group of host counties where the fallout-risk is lowest, and to decrease the hosting ratio to half the average in the group of host counties where the fallout risk is greatest. For example, in Planning Area A, where the average hosting ratio is 4.84 if all counties are used, hosting ratios would vary from 7.26 (14 square feet of living space per person) in lower fallout risk counties to only 2.42 in higher risk counties. The effect of this alternative with respect to the allocation discussed in Section II would be:

	Population (1,000s) in Counties Where There is a 50-50 Chance That Dose Will Be Greater Than 7,000 R, Requiring Category 3 or Better Shelter	
Planning Area	Initial Allocation	Alternative B
A	1,571	1,341
B	116	82
C	2,566	2,098
D	1,607	1,142
E	369	232
Total	6,229	4,895

Overall, there would be a net reduction of about one and a third million people in places where Category 2 shelter would not be adequate at the 50 percent probability level. Alternative B is not nearly as effective as Alternative A, but the requirement for hosting commuting workers might be more nearly met. The effectiveness of this alternative seems to be greater when more stringent standards are considered. Table 20 shows a more detailed comparison of the original allocation with Alternative B at the 75 percent probability level. It can be seen that there is an increase of over 5 million people in areas where Category 1 shelter is adequate, all at the expense of areas where Category 3 or better shelter is required.

The Commuter Hosting Question

A continuing problem in CRP is the identification and dimensioning of essential workers who would need to be hosted, together with their families, in the nearby host area. Various assumptions and planning factors have been employed in other studies and in prototype planning efforts with indifferent success. Ultimately, what will be needed is a major planning effort at the State and interstate level to identify the actions necessary to channel food, fuel, and other consumer essentials to the relocated population in the host counties and thus to specify what risk-area facilities would need to remain in operation during the relocation period. Additionally, such regional planning should identify what defense facilities and defense industry might need to operate in the risk areas depending on the nature of the crisis.

In Section II, we assumed that key workers would constitute 20 percent of the work force (8 percent of the population) and that 20 percent of the population would require close-in hosting accommodations as key workers and their families. This assumption was based primarily on the estimates made in the 1974 pilot projects conducted by DCPA, in which estimates ranged from about 10 percent

Table 20

REQUIRED SHELTER SPACES (Millions)
BY PLANNING AREA AND PF CATEGORY*

CASE I--Uniform Allocation

Planning Area	Category 1	Category 2	Category 3	Category 4	Category 5,6
A	2.7	3.1	1.9	1.7	2.7
B	8.4	7.9	1.0	0.14	0.42
C	3.1	6.0	4.0	2.8	2.3
D	0.65	0.65	0.82	1.3	0.65
E	5.1	0.71	0.19	0.59	0.09
F	1.5	0.09	--	--	--
	21.55	18.52	7.86	6.56	6.05

CASE II--Alternative B (1/6, 1/3, 1/2)

Planning Area	Category 1	Category 2	Category 3	Category 4	Category 5,6
A	3.8	3.7	1.9	1.0	1.7
B	10.9	6.3	0.40	0.27	0.26
C	4.3	7.2	3.5	1.7	1.5
D	0.9	0.9	0.8	0.95	0.45
E	5.7	0.44	0.12	0.36	0.09
F	1.5	0.07	--	--	--
	27.0	18.60	6.70	4.30	4.00

* PF Category based on 75 percent Dose for Summer Winds

to nearly 20 percent. In view of the maximum commuting distances and highway capacity constraints found in the feasibility analysis, we made our own estimate of the number of key workers as a test of the basic assumption.

In our estimate, key workers were defined in three categories--services, manufacturing, and local government--using the following criteria:

- Industrial service workers

  100 percent of trucking and warehousing

  30 percent of banking

  100 percent of wholesale groceries, drugs, petroleum, lumber, and raw farm products

- Manufacturing workers

  Proportions of specified SIC Codes as defined by the Office of Industrial Mobilization

- 100 percent of police, fire, water, and other utilities.

Based on these criteria, estimates were made for New York City, Boston, and two pilot risk areas, Springfield-Chicopee-Holyoke and Utica-Rome. The results, in terms of percent of total risk population, for key workers and dependents were 8.4, 9.2, 5.7, and 4.1 percent, respectively.

It was found that the proportion of key workers in the population was largest in the big cities. But the numbers in New York and Boston were less than half as many as assumed in Section II. This would indicate that a more detailed analysis might make a major change in this aspect of the feasibility of crisis relocation. Moreover, this estimate would allow some consideration of fallout risk in the relocation allocation similar to Alternative B above without major change in necessary commuting distances. There are, of course, uncertainties in the outcome of this matter at the present time. Moreover,

our provisional judgment that the upgrading of existing buildings to provide fallout shelter will not produce much capacity above Category 2 may be too pessimistic as more research and experimentation takes place. Hence, we have not changed our estimate of commuting requirements in Section IV nor have we introduced fallout risk considerations into the allocation at this time.

Highway Capacities

Perhaps the most signal deficiency found in our feasibility study was the inability of the highway system to support the relocation of the populations of the very large cities, especially New York, Boston, and Philadelphia, over a three-day period. Therefore, a good deal of thought was devoted to consideration of what could be done to improve this situation. As will be noted in the next section, our proposed modifications of the definitions of blast and fallout risk cause a substantial reduction in the numbers of people, and hence vehicles, required to cross the cordons. This will reduce the time required to clear the large risk areas to some extent.

Our assumptions with respect to highway capacities under normal operating conditions are not unduly pessimistic. Although a few past studies have assumed that conditions of ideal traffic flow could be maintained around the clock,[16,17] it seems extremely unlikely that this could be the case. Indeed, one investigator[18] has made the assumption that flow would occur only 16 hours a day. (Our assumption is that maximum capacity could be maintained 20 hours per day.) Therefore, we are of the opinion that improvements in highway capacity must come largely from changes in the conditions of utilization of the existing highway net.

It will be recalled that our highway capacity assumptions in the feasibility analysis were:

- 1,500 cars per hour per lane on divided limited-access highways
- 1,200 cars per hour per lane on divided highways
- 900 cars per hour per lane on undivided two-way highways
- Movement limited to a 20-hour day.

In assessing the capacity of a particular highway, we tended to be somewhat conservative. When in doubt as to the class of highway or the number of usable lanes, we conducted telephone interviews with highway authorities in the area. In the process, it is possible that we omitted some roads across the cordons that could have been used effectively and that we underrated the service on certain roads. A more detailed analysis, particularly in the New York area, is probably desirable in this respect. There are, however, only two techniques available that are likely to make a significant improvement in the overall capacity of the highway system leading from the major seaboard population centers: one must either change the highway type or increase the effective number of outbound lanes.

In the first instance, changing an undivided highway to a divided type in order to increase lane capacity under our assumptions undoubtedly has very limited application. Some four-lane undivided highways might be modified in a crisis if they constituted a bottleneck over a short distance. Two-lane streets are often upgraded by making alternate streets one-way. But both of these possibilities are largely applicable within the risk area. Making an already divided multilane highway limited in access is a possibility of wider application. An example in the New York area is the Saw Mill River Parkway feeding the Taconic State Parkway into Putnam and Dutchess Counties. Both are currently classed as divided four-lane highways. The two outbound lanes are rated at 2,400 cars per hour, 48,000 cars per day, or 144,000 cars over a three-day period. There are less than a half-dozen signal-controlled intersections on this route.

All remaining access is limited to overpass interchanges. It should be a simple matter to plan to block the offending intersections and to convert this important route to the limited-access variety, in which case the two outbound lanes might be rated at 3,000 cars per hour, or 180,000 in a three-day period. Highways such as this, which do not have significant access from private drives and feeder streets, probably should be considered for upgrading for crisis relocation.

Increasing the number of effective outbound lanes on a highway is a more powerful technique in most instances. On multilane highways, the available lanes can be regulated in various ways (and often are in commuter areas), shoulders and parking lanes can be used for an extra lane of traffic, and the like. A detailed survey of the route is usually needed to determine what is possible. The ultimate in this approach is to make all lanes outbound on one or more routes.

Most evacuation planning conducted in the 1950s was based on the option of making all highways one-way outbound. By this means, one can conceivably double the capacity of the route. The application of this solution to CRP appears to be rather controversial. All in all, the technique seems more difficult than it did two decades ago. For example, Hubenette et al. observe:[19]

> The initiation of wrong-way flow would be difficult and time-consuming. Sequential phasing would have to be developed so that upstream on-ramps were closed and traffic on the freeway directed off at certain off-ramps. This ramp closure and freeway clearing would involve physical control to guarantee success. The reliability of signs to perform the task is doubtful, since 100 percent clearing of the freeway would be required. One car proceeding in the direction opposite to the heavy flow could completely block the freeway by causing one major head-on collision.
>
> Only after the freeway had been completely cleared could the wrong-way flow be initiated. A second series of signs or other control devices would be required to initiate the flow. Since the wrong-way flow would follow the initiation of directed evacuation,

> it would be impractical to make specific assignments to the wrong side of the freeway unless a rigidly controlled evacuation were planned. That is, it would be impractical to advise a portion of the population to wait until the freeway was clear before they started their movement operation. If specific assignments could not be made, use of the wrong side of the freeway would depend solely on traffic control devices or manual control by a uniformed officer.
>
> The geometrics of existing off-ramps are such that they tend to make a wrong-way turn difficult. The paths traveled by vehicles attempting to use the off-ramps as on-ramps would be awkward. Also, since motorists would be proceeding in the wrong direction, they would have to use on-ramps as off-ramps. The terminals of most on-ramps at the street intersection are such that it would be difficult to turn onto the street in the proper direction.

Billheimer[18] tends to agree with this analysis to the extent of observing that there are several factors that appear to lessen the value of using the wrong side of a freeway. He also notes that, "In a sense, establishing one-way flow on surface streets would be even more difficult than establishing one-way flow on freeways, since surface streets have far more access points that will have to be controlled."

There are some points to be made on the opposite side. The plans of the 1950s were tactical evacuation plans, with the highways, of necessity, being converted to one-way outbound with extremely short warning. State and local officials of the time believed that they could accomplish this conversion. In crisis relocation, by contrast, at least six hours of mobilization is being planned prior to a public directive to relocate. There is small doubt that traffic rerouting will be effective under these circumstances.

The Bureau of Public Roads did a landmark study, A Preliminary Report on Highway Needs for Civil Defense,[10] in 1956 that formed part of the basis for the Interstate highway system. The Interstate system was justified in large part for national defense (evacuation)

purposes. The BPR report specifically contemplated that all lanes of these and other routes could be used in the same (outward) direction during emergencies. Off-ramps at interchanges are protected by conspicuous WRONG WAY signs but the access is convenient enough that motorists enter the off-ramps on occasion. Moreover, utilization of all lanes can be accomplished readily by crossing the median as well as by using off-ramps for entry and on-ramps for exit.

If highways, which are among the most valuable resources for crisis relocation, are to be used to full capacity, adequate planning and operational control are essential. Essential elements of a traffic management scheme, as we see it, include placement of control personnel at freeway ramps to control and meter access and at street and highway intersections to prevent or regulate cross traffic; deployment of highway patrol and other mobile units to deal with accidents and other stoppages and to provide minor supplies and repair services along the route; employment of a surveillance subsystem of traffic counting devices, trained observers at fixed positions, in automobiles, and in aircraft, and suitable communication links; operation of a control center capable of digesting surveillance reports and other intelligence and issuing operating instructions; and development of effective means of communicating with the drivers of vehicles both by radio and by means of simple signs and signals. It would seem that preparations of this kind will be necessary whether or not some routes are made one-way outbound since the entry of vehicles on each route must be scheduled at relatively uniform and appropriate flow rates to assure full utilization of capacity or to prevent overloads and resulting unstable flow and stoppages.

It would seem that if there is a clear need to convert major highways to serve only outbound traffic in order to evacuate large risk areas, such as New York, a major need will be to provide for the recirculation of highway police and emergency vehicles that must move outward in the stream of relocation vehicles and return

upstream periodically. This is possible if streets or a lesser highway run parallel to the major highway and can be used for recirculation. The Interstate system and other major limited-access routes are of particular interest in this respect because they generally parallel and replace an older highway. In the Northeast Corridor, the matching of Interstate 95 and US 1 is an excellent example. This situation is common throughout the study area but needs to be planned in detail in each area.

In this study, it has not been possible to study each route in detail, as ought to be done, particularly in the New York area. For this reason, we have limited ourselves to increasing highway capacity where needed by making routes one-way outbound although the planners might well opt for other alternatives for adding lanes or controlling access on the basis of detailed knowledge and consultation. To some extent, we have also considered the option of dedicating lanes or routes to bus and truck traffic.

IV SOLUTION UNDER EXISTING POLICIES AND GUIDANCE

In this section, we present the "best" solution to the problem of crisis relocation in the Northeast Corridor study area, as we have been able to determine it, within the general limitations of current DCPA policies and guidance. We have, for this purpose, made some modifications to the assumptions and criteria that governed the initial feasibility analysis (Section II) but not to the extent that these modifications can be considered revolutionary. More radical alternatives are discussed in Section V. As will be noted several times in this section, the solution presented here is subject to further improvement by successive iterations that would more completely integrate the transportation analysis with the allocation procedure. For this reason, average and maximum relocation distances given here are somewhat higher than might be expected if a more thorough planning effort were undertaken. The lack of adequate information on county hosting capacity was a major reason for not pursuing the analysis beyond that appropriate to a test of feasibility.

Population Adjustments

As discussed in the previous section, the original risk criteria are considered deficient and have been modified to eliminate from the blast-risk population persons residing in "urbanized tentacles" that are not actually at blast risk nor part of the main body of urbanization and to eliminate from the fallout-risk population persons residing in MCDs of "green" counties where the probable dose is less than 10,000 R. Additionally, we have taken the opportunity to correct deficiencies in the population input data. The computer printouts, for example, not only contain some errors but also are based on preliminary census data for 1970. Other data used in the analysis are based on later data. Therefore, the population count at the MCD level in the study area was adjusted to the final "official" 1970 Census figures.

The population adjustments are summarized below for the entire study area:

Population Element	Section II	Section IV
Total	60,439,648	60,682,277
Blast risk	46,881,896	46,107,000
Fallout risk	1,700,081	1,617,126
Host areas	11,857,671	12,968,181

The updating of 1970 Census data added about a quarter million persons to the total study area population, a fractional percentage increase. Elimination of urban tentacles withdrew about three-quarters of a million people from the blast-risk population of nearly 47 millions. Use of fallout-risk data at the MCD level decreased the overall number of people at fallout risk by about 5 percent. These are not large changes. They are indicative of the fact that the adjustments do not do violence to current policies and guidance. They do not "define away" the problem of crisis relocation in areas of high population density.

At the same time, it will be noted from the tabulation above that the host population in the study area has been increased by 1.1 million persons, an increase of about 10 percent. As will be seen, this shift, modest as it is, exerts remarkable leverage on the problems of crisis relocation in the Northeast Corridor. Overall, these results are a convincing demonstration of the necessity for careful control by the Federal Government of the dimensioning of crisis relocation in areas of high population density.

Planning Areas and Allocation

A standardized hand method of allocation--the 20 percent slice method--was used for the final allocation of the blast-risk population to the host areas. On the basis of experience with earlier allocations, three of the six planning areas were subdivided into subareas and one, Planning Area F (West Virginia), was dropped from the allocation. Figure 9 shows how the planning areas were subdivided. New England was divided into two subareas, A1 and A2. New Jersey-Pennsylvania was divided into a northern area (C1) and a southern

Figure 9 FINAL PLANNING AREAS AND SUBAREAS

area (C2). Planning Area E has been divided into three subareas--Washington (E1), the Norfolk tidewater area (E2), and the remainder of Virginia. These subdivisions were made for ease of hand computation according to the procedures that will be incorporated into the draft guidance and because the relocation flow in each subarea is substantially independent of the others. As will be noted on Figure 9, West Virginia, except for the panhandle counties within Area D, is not included since the crisis relocation plan for Area F is not part of the Northeast Corridor problem under current planning assumptions.

The final allocation for the Northeast Corridor Study, which incorporates the population adjustments discussed above, is exhibited in Table 21 and in Appendix 2. For each of the areas shown in Figure 9, there is a summary in Table 21 that lists the risk jurisdictions and their risk populations, along with the average and maximum relocation and commuting distances resulting from the allocation. The detailed allocation of population from each risk jurisdiction to various host counties is given in Appendix 2. Outside of New England--areas A1 and A2--risk counties were allowed to preempt any hosting space within the same county for their own risk population to the extent necessary. These risk counties (and independent cities in Virginia) are indicated by an asterisk in Table 21 and have nominal relocation distances. They are generally omitted from the allocation summary in Appendix 2. The host capacities shown in Appendix 2 are simply five times the host population, except for the asterisked counties, where the space required by the indigenous risk population has been deducted prior to the main allocation. Also, the area summaries in Table 21--the "bottom line"--generally do not include the short relocation distances (and population) of the asterisked counties, as to do so would bias the results to lower values in a way that would be misleading.

Some discussion of these results is warranted to place them in the proper context. We refer to the first page of Table 21, which covers eastern New England, including the Boston area. The average

Table 21

ALLOCATION SUMMARY (1)

PLANNING AREA A1 -- EASTERN NEW ENGLAND

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population (1000s)	Average	Maximum	Average	Maximum
New London CT	148.7	156	287	17	43
Washington RI	52.4	145	263	8	8
Newport RI	91.8	122	268	15	17
Kent RI	142.4	136	258	29	29
Bristol RI	45.9	135	258	20	20
Providence RI	581.5	142	253	36	43
Nantucket MA	3.8	30 miles by ferry boat			
Barnstable MA	19.2	171	288	13	13
Bristol MA	444.3	162	270	53	53
Plymouth MA	218.3	141	242	32	32
Norfolk MA	590.5	137	255	74	75
Middlesex MA	1300.0	127	235	64	64
Suffolk MA	735.2	148	274	68	68
Worcester MA	584.9	158	271	48	58
Essex MA	554.3	132	226	49	49
Hillsborough NH	188.6	121	229	31	31
Rockingham NH	93.1	109	244	26	26
Merrimack NH	5.6	111	223	15	15
Strafford NH	32.7	104	245	11	11
York ME	23.7	133	241	30	30
Cumberland ME	153.0	136	195	17	17
Sagadahoc ME	15.7	117	256	16	16
Androscoggin ME	71.1	134	251	11	11
Hancock ME	1.2	38	44	7	7
Penobscot ME	53.8	133	157	36	36
Aroostook ME	11.6	13	13	13	13
AREA A1	6163.3	138	288	50	75

Table 21

ALLOCATION SUMMARY (2)

PLANNING AREA A2 -- WESTERN NEW ENGLAND

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population (1000s)	Average	Maximum	Average	Maximum
Fairfield CT	750.3	137	250	21	21
New Haven CT	744.9	140	247	36	43
Middlesex CT	71.3	121	213	39	39
Litchfield CT	94.3	113	213	18	18
Hartford CT	815.4	119	254	31	42
Tolland CT	79.2	129	252	42	42
Hampden MA	456.1	118	274	17	18
Hampshire MA	80.3	110	256	10	10
Berkshire MA	80.4	136	227	22	22
Chittenden VT	83.1	86	105	10	10
AREA A2	3255.3	127	274	27	43

NOTE: The risk populations of the New York counties within Area A2 are hosted within their own boundaries. The hosting capacities of these counties used in the allocation are the net amounts after accommodating their risk populations.

Table 21

ALLOCATION SUMMARY (3)

PLANNING AREA B -- NEW YORK STATE

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population (1000s)	Average	Maximum	Average	Maximum
Suffolk	1061.4	149	255	22	51
Richmond	295.4	157	252	52	52
Kings	2602.0	149	248	38	46
Nassau	1428.8	165	269	70	79
Queens	1987.1	151	262	70	71
New York	1539.2	156	260	60	60
Bronx	1471.7	158	267	58	58
Westchester	750.9	141	278	10	10
Rockland	191.9	148	268	10	10
Albany	279.1	136	166	27	27
Rensselaer	128.7	22	173	10	10
Saratoga*	35.6	10	10	10	10
Schenectady	157.3	123	151	16	16
Herkimer*	10.8	10	10	10	10
Oneida*	216.8	10	10	10	10
Madison*	29.4	10	10	10	10
Onondaga	472.8	39	52	33	33
Oswego*	19.3	10	10	10	10
Broome*	91.3	10	10	10	10
Monroe	608.4	13	31	10	10
Erie	985.3	16	37	10	10
Niagara*	160.9	10	10	10	10
Wayne, PA*	5.3	10	10	10	10
New York SMSA	11328.4	153	278	50	79

(*) The risk populations of the asterisked counties are hosted entirely within the county boundaries. Therefore, these counties are not included in the allocation as risk counties and their hosting capacities, if any, are the net amounts after accommodating their risk populations.

Note also that with the exception of Albany and Schenectady Counties, the relocation distances for risk counties outside the New York SMSA are nominal. Therefore, the bottom line applies only to the top group of counties.

Table 21

ALLOCATION SUMMARY (4)

PLANNING AREA C1 -- NORTHEAST NEW JERSEY

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population (1000s)	Average	Maximum	Average	Maximum
Bergen NJ	897.1	116	190	33	48
Hudson NJ	609.3	120	193	41	55
Essex NJ	932.3	124	187	49	49
Passaic NJ	443.5	131	185	44	48
Union NJ	543.1	135	190	52	52
Middlesex NJ	574.7	121	186	39	39
Morris NJ	334.6	118	194	10	10
Somerset NJ	142.9	117	184	10	10
Sussex NJ	23.8	102	168	10	10
Hunterdon NJ	18.8	104	168	10	10
Warren NJ	33.4	98	163	10	10
Lehigh PA*	190.0	10	10	10	10
Northampton PA	181.6	25	165	10	10
Lackawanna PA	230.5	82	141	18	18
Luzerne PA*	252.2	10	10	10	10
Monroe PA*	3.5	10	10	10	10
Wyoming PA*	12.8	10	10	10	10
Erie PA*	206.0	10	10	10	10
NE NJ AREA	4553.5	122	194	39	55

(*) The risk populations of the asterisked counties are hosted entirely within the county boundaries. Therefore, these counties are not included in the allocation as risk counties and their hosting capacities, if any, are the net amounts after accommodating their risk populations.

Note also that with the exception of Northampton and Lackawanna Counties, Pennsylvania, the relocation distances for counties outside the Northeast New Jersey part of the New York Consolidated Area are nominal. Therefore, the bottom line applies only to the New Jersey counties.

Table 21
ALLOCATION SUMMARY (5)
PLANNING AREA C2 -- PHILADELPHIA-SOUTH JERSEY

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population (1000s)	Average	Maximum	Average	Maximum
Monmouth NJ	413.0	123	223	70	70
Ocean NJ	32.6	123	218	74	74
Atlantic NJ	47.5	128	220	76	76
Cumberland NJ	34.1	105	190	57	57
Burlington NJ	316.2	101	222	41	41
Mercer NJ	304.0	94	212	26	26
Camden NJ	434.5	92	208	34	34
Gloucester NJ	140.2	97	206	32	32
Salem NJ	42.0	87	184	39	39
Philadelphia PA	1950.1	87	231	15	15
Bucks PA	344.7	100	233	10	10
Montgomery PA	495.9	93	222	10	10
Delaware PA	590.3	94	220	23	23
Chester PA*	6.6	10	10	10	10
Berks PA*	187.8	10	10	10	10
Lancaster PA*	232.0	10	10	10	10
York PA	260.4	110	179	14	30
Dauphin PA	188.5	18	137	10	10
Perry PA*	2.3	10	10	10	10
Cumberland PA*	95.0	10	10	10	10
Adams PA*	16.6	10	10	10	10
Franklin PA	85.9	25	124	10	10
Blair PA*	104.8	10	10	10	10
Cambria PA*	121.2	10	10	10	10
Somerset PA*	16.0	10	10	10	10
Indiana PA*	5.3	10	10	10	10
Westmoreland PA*	254.5	10	10	10	10
Allegheny PA	1605.1	39	70	28	28
Washington PA	98.3	52	62	10	10
Beaver PA	169.8	19	25	10	10
Butler PA	42.1	17	28	10	10
Armstrong PA*	55.3	10	10	10	10
Lawrence PA*	8.3	10	10	10	10

(*) The risk populations of the asterisked counties are hosted entirely within the county boundaries. Therefore, these counties are not included in the allocation as risk counties and their hosting capacities, if any, are the net amounts after accommodating their risk population.

Note also that with the exception of York County, the relocation distances for counties outside the Philadelphia-New Jersey area are nominal. The summary data for the New Jersey and first four Pennsylvania counties above are:

5150.1	95	233	25	76

Since there is surplus hosting capacity in the Pittsburgh area, the allocation which produced the short relocation distances shown above is not significant and is not included in the allocation summary.

Table 21

ALLOCATION SUMMARY (6)

PLANNING AREA D -- BALTIMORE-WILMINGTON

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population	Average	Maximum	Average	Maximum
Kent DE	49.9	66	74	36	36
New Castle DE	375.8	82	122	21	21
Anne Arundel MD	286.7	77	105	55	55
Baltimore MD	612.0	93	141	37	53
Baltimore City	905.8	96	140	47	47
Harford MD	106.4	112	155	38	38
Howard MD	62.4	94	130	37	37
Kent MD	4.2	87	99	36	36
Frederick MD*	27.3	10	10	10	10
Washington MD	93.6	50	99	10	10
Alleghany MD*	40.0	10	10	10	10
AREA D	2564.1	88	155	39	55

(*) The risk populations of Frederick and Alleghany Counties, Maryland are hosted entirely within the county boundaries. Therefore, these counties are not included in the allocation as risk counties and their hosting capacities, if any, are the net amounts after accommodating their risk populations.

Table 21

ALLOCATION SUMMARY (7)

PLANNING AREA E1 -- WASHINGTON AREA

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population (1000s)	Average	Maximum	Average	Maximum
District of Columbia	756.5	86	147	24	24
Montgomery MD	518.6	87	148	25	29
Prince Georges MD	657.4	102	155	32	32
Charles MD	16.1	70	144	27	27
St. Marys MD	19.8	80	158	28	40
Arlington VA	174.3	87	135	16	16
Fairfax VA	487.8	83	137	15	25
Alexandria VA	110.9	87	137	20	20
Loudoun VA*	14.0	10	10	10	10
Prince William VA*	24.8	10	10	10	10
Fauquier VA*	6.5	10	10	10	10
Stafford VA*	4.1	10	10	10	10
AREA E1	2741.4	89	158	24	40

(*) The risk populations of the asterisked counties are hosted entirely within the county boundaries. Therefore, these counties are not included in the allocation as risk counties and their hosting capacities are the net amounts after accommodating their risk populations. Relocation distances for these counties are not included in the Area summary.

Note also that the independent cities of Fairfax and Falls Church are included in the Fairfax County risk population.

Table 21

ALLOCATION SUMMARY (8)

PLANNING AREA E2 -- NORFOLK AREA

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population (1000s)	Average	Maximum	Average	Maximum
York VA	33.2	41	69	13	14
Hampton City	120.8	55	76	33	33
Newport News City	138.2	49	68	28	29
Williamsburg City	9.1	32	81	10	10
Norfolk City	308.1	49	94	13	13
Portsmouth City	111.0	42	75	11	11
Virginia Beach City	172.1	53	95	31	31
Chesapeake City	89.6	40	73	9	9
Accomack*	9.7	10	10	10	10
Gloucester*	8.6	10	10	10	10
Isle of Wight*	7.9	10	10	10	10
James City Co.*	12.4	10	10	10	10
Charles City Co.*	2.9	10	10	10	10

(*) The risk populations of the asterisked counties are hosted entirely within the county boundaries. Therefore, these counties are not included in the allocation as risk counties and their hosting capacities are the net amounts after accommodating their risk populations. The summary data for Area E2, neglecting the asterisked counties, are as follows:

AREA E2	982.1	48	95	20	33

Table 21

ALLOCATION SUMMARY (9)

PLANNING AREA E3 -- SOUTHERN VIRGINIA

People at Blast Risk		Relocation Distance		Commuting Distance	
County	Population	Average	Maximum	Average	Maximum
Prince Georges	26.5	22	39	10	10
Colonial Hts City	15.1	17	34	10	10
Hopewell City	23.5	16	57	10	10
Petersburg City	36.1	26	37	10	10
Richmond City	249.4	10	10	10	10
Lynchburg City	54.1	16	19	10	10
Roanoke City & County	159.5	18	20	10	10
Salem City	22.0	22	22	10	10
Bristol City	14.9	16	16	10	10
Chesterfield*	56.5	10	10	10	10
Dinwiddie*	20.5	10	10	10	10
Henrico*	58.2	10	10	10	10
Nottoway*	5.9	10	10	10	10
Amherst*	17.1	10	10	10	10
Campbell*	29.0	10	10	10	10
Botetourt*	6.7	10	10	10	10
Pulaski*	18.6	10	10	10	10
Radford City	11.6	9	10	9	9
Scott*	5.3	10	10	10	10
Washington*	25.8	10	10	10	10

(*) The risk populations of the asterisked counties are hosted entirely within the county boundaries. Also, Radford City has ample hosting within Pulaski County. Therefore, these counties and Radford City are not included in the allocation as risk counties and their hosting capacities, if used in the allocation, are the net amounts after accommodating their risk populations.

There is a large surplus of hosting capacity in Area E3 at a hosting ratio of 5. Many counties in the area are not included in the allocation as they are not necessary. The relocation distances in this area average about 20 miles, indicating a great deal of flexibility in relocation planning.

relocation distance for the risk populations in this area is 138 miles. Within this average, note that two small risk populations in upper Maine have very much lower average travel distances, 13 and 38 miles, because they are remote from the main population centers and have no competition for the nearby hosting space. Otherwise, the average relocation distance by county varies from a low of 104 to a high of 171 miles. This is a reasonable measure of the amount of equity that is built into the hand allocation method.

The maximum relocation distance, 288 miles, results from our allocation rule for New England, which forces 80 percent of the small risk population in Barnstable County, Massachusetts (Cape Cod) to relocate to the north of Boston. In an actual CRP, the undesirability of this move would probably be recognized. The population would be hosted nearby on the Cape at the expense of some critical workers from other risk areas. If this modification were made, the overall maximum would change little unless the 287-mile maximum for New London, Connecticut, can be reduced in some way.

The maximum relocation distance for New London comes about from the assignment of 6,000 persons to Somerset County, Maine. No closer hosting space is available according to our allocation rules if these people must relocate by highway. There is, however, an airport at New London that could handle at least 36,000 relocatees in a three-day period. There is also a suitable airport at Presque Isle, Aroostook County, Maine, a county with much unused hosting capacity because of its remoteness. The Census data indicates that 89.6 percent of the population of New London County have first autos. Of the remainder who require other means of transportation, about 20 percent are likely to be classed as key workers and dependents. Thus, about 12,370 persons are available for airlift. Assigning this number for airlift to Aroostook would eliminate the need for the Somerset assignment and make Sagadahoc County the most remote highway assignment (or rail assignment) for New London. The maximum relocation distance except for the air transport would become 225 miles.

Returning to the first page of Table 21, the next longest maximum relocation distance is found to be 274 miles for Suffolk County, Massachusetts. A similar analysis would be in order to see if the most remote assignment for Suffolk County could be eliminated in some way by use of land, sea, or rail travel. If this successive integration of the elements of the transportation analysis into the allocation procedure were carried through, it seems likely that the maximum relocation distances given in Table 21 could be reduced substantially. Needless to say, these modifications should be undertaken in regional planning and are discussed in the draft guidance.

Overall, the situation described by the allocation summaries in Table 21 is representative of the "best solution" likely in the study area within the context of current policies and guidance. This situation represents a substantial improvement in relocation and commuting distances, as summarized in Table 22. In this table, the "old" distances are those of Section II and the "new" distances are from the final allocation. For Planning Areas A, C, and E, the new data are for the subarea associated with the named metropolitan area. In all cases, the distances for the other subareas (A2, C1, E2, and E3) are less than for the ones cited. Even so, the overall average relocation distance in the Northeast Corridor is now less than 100 miles and the maximum is less than 300 miles. Moreover, the average commuting distance is only 42 miles and the maximum is only 79 miles. Thus, the adjustments that have been made have resulted in significant improvement in the problem cases of Section II.

It will be noted in Table 22 that the "new" distances are occasionally larger than the earlier distances, notably the Baltimore relocation distances and the Boston maximum commuting distance. These anomalies in the general pattern of distance reduction are a consequence of particular population adjustments and the standardization

Table 22

COMPARISON OF RELOCATION AND COMMUTING DISTANCES

PLANNING AREA	METROPOLITAN AREA	RELOCATION DISTANCE (mi) Average (Old)	(New)	Maximum (Old)	(New)	COMMUTING DISTANCE (mi) Average (Old)	(New)	Maximum (Old)	(New)
A (A1)	Boston	170	138	290	288	50	50	55	75
B	New York	188	153	319	278	77	50	94	79
C (C2)	Philadelphia	133	95	262	233	64	25	112	76
D	Baltimore	83	88	141	155	40	39	84	55
E (E1)	Washington	120	89	220	158	24	24	40	40
Northeast	Corridor (Final)		97		288		42		79

of the allocation procedure. As noted above, the maximum relocation distances shown are longer than necessary for highway travel.

Fallout Considerations

The final allocation exhibited here gives no explicit consideration to the potential fallout risk associated with specific host counties beyond the hosting cutoff dose of 10,000 R. The population adjustments that have been made were motivated by a need to minimize the numbers of people evacuating across the key cordon lines and to reduce commuting and relocation distances. The change in fallout risk associated with this approach is shown by the following comparison:

	Population at Risk from Fallout	
	Initial Allocation 000's	Final Allocation 000's
Counties where there is a 50-50 chance dose will be:		
Greater than 20,000 R	241 (0.4%)	280 (0.5%)
Greater than 15,000 R	771 (1.2%)	945 (1.6%)
Greater than 10,000 R	1,513 (2.5%)	1,742 (3%)
Greater than 7,000 R	6,229 (10%)	7,099 (12%)
Greater than 4,000 R	15,478 (26%)	17,257 (29%)
Greater than 2,000 R	32,295 (53%)	34,166 (58%)
Less than 2,000 R	28,145 (47%)	24,838 (42%)
Total Population	60,440 (100%)	59,004 (100%) (Area F omitted)

The "initial allocation" shown here is the one described in Section II and is associated with Table 14. The two allocations do not have quite the same basis. For one thing, Planning Area F (West Virginia) was not included in the final allocation but was in the initial allocation. Over 90 percent of the population in Area F were found in areas with a probable dose of less than 2,000 R. On

the other hand, the relocatees in the Pittsburgh area have been included but not on the basis of a specific allocation. It is likely that they, who number about the same as those in Area F, would be located in somewhat higher dose levels than the average in their planning area. The two differences probably compensate for each other rather well.

It will be noted from the table that the number of people in "green" areas--with probable doses greater than 10,000 R--is increased in the final allocation from 2.5 percent to 3 percent of the population. The explanation is that some of the urbanized tentacles, such as the coastal area of New Jersey, no longer are scheduled for relocation. They remain in the green counties along with their non-urbanized neighbors. Similarly, some of the increase in lower categories is due to the use of MCDs near the larger risk areas for hosting on the basis of the detailed fallout calculation discussed in Section III. Some of these areas, which were used for the hosting of critical workers, were in the higher probable dose categories. It will be recalled that the initial allocation used the entire hosting area uniformly without concern for highway routes or distances. The final allocation, of course, attempts to minimize relocation and commuting distances. The cost of this emphasis is represented by the increase of about 3 percent of the total population shifted to areas with a probable dose in excess of 4,000 R, nearly 2 million additional people.

In Section III, we discussed alternative ways to take fallout risk into account in the allocation process. As a check on the sensitivity of the final allocation to consideration of fallout risk, we

performed an alternate allocation for one area, A2, western New England. We ranked the host counties in order of increasing fallout risk, together with their nominal hosting capacities at the 5 to 1 hosting ratio. The total hosting capacity was then partitioned into approximately three equal groups. The set of counties in the group with the highest probable doses was given a new hosting capacity only one-half of the previous amount. To compensate, the hosting capacity of the counties in the group of lowest probable dose was increased by 50 percent. In other words, one-sixth of the total hosting capacity of the planning area was moved from the counties at greatest risk to those at least risk. A new allocation was then performed using the standardized method.

The change in **fallout risk** for the relocated population in subarea A2 can be summarized as follows:

	Percent of Blast-Risk Population	
	Final Allocation	Modified Final Allocation
Relocated to counties where there is a 50-50 chance dose will be:		
Less than 2,000 R	24	37
Greater than 2,000 R	76	63
Greater than 4,000 R	36	18
Greater than 7,000 R	10	5
Greater than 10,000 R	0	0

In neither case were any blast-risk population allocated to areas with a probable dose greater than 10,000 R. The payoff of the modified final allocation was that it cut in half the number allocated to areas over 4,000 R and increased those in low-risk areas substantially. The effect on the average relocation distance in western New England was to increase it from 127 miles (Table 21) to 151 miles. The maximum travel distance was increased from 274 miles to 296 miles. The average relocation distance is still considerably less than the 170 miles established in the feasibility study of Section II and the maximum distance is about the same. From a commuting standpoint, there was negligible impact. The average was increased from 27 miles to 30 miles; the maximum of 43 miles was not increased. Although subarea

A2 was selected as somewhat typical, there is no assurance that the results just given are representative. Nonetheless, it would seem that a modified allocation of the type used here might well be a useful option.

Revised Transportation Analysis

The population adjustments made for the final allocation had a significant effect on the numbers of vehicles crossing the key cordons we used to assess the feasibility of available highway capacity to support crisis relocation within a three-day period. The results are shown in Table 23. This table can be compared in general with Table 9 in Section II. Highway capacity assumptions are unchanged, but the revised analysis shown here included a tracing out of the origins and destinations of relocation traffic as defined in the final allocation given in Appendix 2. This procedure resulted in some modifications in the earlier estimates. The details are summarized for each of the metropolitan areas listed in Table 23 in Appendix 3, which should be consulted for the basis of the calculations.

Table 23 describes the situation in the major evacuation centers with respect to first automobiles only. It was found earlier, however, that first automobiles dominated the problem of highway capacity. The next-to-last line in the table indicates the time required to pass all first automobiles over the cordons, assuming that the highways are used in their normal two-way mode. The only exception occurs in the New York area, where it was assumed that the few traffic lights and uncontrolled accesses on the Saw Mill River Parkway and Taconic State Parkway were blocked so that it could be assumed to have the capacity of a limited-access divided highway. It can be seen that only in the case of the westward flow from Baltimore would the highways permit an exodus in less than three days. In Boston and Washington, the time required would exceed three days by only an hour or so. The worst situation is in the New York area where somewhat over five days would seem necessary.

If the limited-access highways (and only these highways) were made one-way outbound for the period of relocation, the times shown in the bottom line are appropriate. In all cases except Philadelphia the time

Table 23

REVISED CORDON COUNT

	Boston-Providence	New York	Philadelphia-So. New Jersey	Baltimore-Wilmington	Washington
Population relocatable by first automobile	4,015,400	6,439,600	3,491,100	1,864,300	2,219,800
First automobiles	1,253,200	2,075,200	1,083,700	564,000	702,600
Autos across cordon	777,190	1,883,820	1,083,700	312,000	702,600
Available lanes	10	14	13	5	11
Three-day capacity	756,000	1,116,000	882,000	342,000	684,000
Shortage	21,190	767,820	201,700	OK	18,600
Relocation period (days) (normal use of highways)	3+	5+	3 1/2	<3	3+
Relocation period (days) (limited-access highways one-way out)	<2	<3	3+	--	<3

is estimated to be less than three days, thus allowing some time for bus and truck movement or the dedication of one or more two-way routes to bus and truck round trips. In the Boston area, the estimated time is less than two days, indicating that not all limited-access routes need be made one-way. In the Philadelphia area, however, the time required is still in excess of three days because there is only one limited-access highway (the Pennsylvania Turnpike) leading to the west. (Interstates 78 and 80 to the north service the northeast New Jersey conurbation.) To reduce the relocation time in the Philadelphia area to less than three days would require that US 30 and perhaps US 1 be made one-way outbound or else the inbound traffic confined to one lane.

A bit of caution should be used in interpreting these results. In the first place, they presume that all vehicles traverse the routes during the relocation period--there is no earlier spontaneous evacuation and no one refusing to leave. As a practical matter, some substantial but unquantifiable portion of the traffic load would not occur. In addition, our cordon analysis is intentionally conservative. There are undoubtedly many roads crossing the cordons that have not been included in our calculations because it was unclear how they would be used in a detailed plan. For example, all routes listed in Appendix 3 are Interstate, Federal, or State highways. Not all State or US highways are represented. Only a more detailed transportation analysis is likely to result in identification of additional highway capacity.

The foregoing disucssion concerns first automobiles only. Although a majority of the risk population can be relocated by means of their own vehicles in all cases, the relocation of those without access to an automobile is a major planning problem in the large metropolitan areas. Since highway capacity is demonstrably strained by the numbers of first automobiles to be handled, rail and air modes of transport should be used to the greatest extent possible for carless relocatees. The detailed analysis of these resources--to the extent feasible within this effort--

is summarized in Appendix 3. In general, non-highway modes of transport can move only a fraction of those requiring it. The primary resource available in the big cities is large highway vehicles, buses and trucks. These, of course, compete with private automobiles for highway capacity.

When the full relocation requirement is considered, it is found that the goal of relocation within a three-day period is not achievable in the large metropolitan areas unless the limited-access highways leading to the host areas are made one-way outbound. In the Philadelphia area, at least one US divided highway must also be made one-way. If this measure is accepted as practical, as we believe it is, then all large risk areas except New York City can be emptied within a three-day period. In New York, four days are required even if limited-access routes are converted to the one-way mode. The basis for these conclusions is recapitulated in Appendix 3.

Feasibility of Commuting

An assessment of the commuting problem in each metropolitan area listed in Table 23 will be found in Appendix 3. The results are probably best evaluated with respect to the characteristics of normal weekday commuting in the same areas. The population adjustments made in this section have reduced the distances to be commuted to a reasonable average of just over 40 miles and a not unreasonable maximum for some commuters of just under 80 miles. Commuting time for an uninterrupted trip would be one to two hours, somewhat greater than normally encountered.

However, the number of commuters assumed in this study--which may be excessive, as discussed in Section III--stress the highway capacity in all the major urban areas. The commuting period--the time period required for all the commuter traffic to move past the boundary of the risk area--was found to range from 3 1/2 to 10 hours. If it is

assumed that essential workers perform their risk activities as two shifts, then each shift change would involve a commuting period of from under two hours to nearly five hours. Commuting periods of two to three hours' duration are normally observed in everyday practice in the large cities. Formal or informal arrangements for staggered working hours are commonplace. Such arrangements will be an essential part of crisis relocation planning for the large metropolitan centers.

The critical commuting problems--those that result in abnormally long commuting periods--are associated with highway bottlenecks, usually bridges. The most serious example found in Appendix 3 is the Chesapeake Bay bridge, which is, according to the final allocation, to be used by a large part of the Baltimore critical work force who are relocated to the Maryland Eastern Shore. Another case involves two bridges across the Cape Cod Canal that must be traversed by commuters hosted on Cape Cod. Our view is that these kinds of problems can usually be ameliorated by adjusting the allocation to assign fewer critical workers to these locations at the cost of a small increase in the commuting distance. In other words, there is a trade-off between commuting distance and highway capacity that is best determined as part of the detailed planning process.

Because of the generally satisfactory nature of these results, we did not find it necessary to evaluate in any detail the alternatives to commuting mentioned in the scope of work, such as sheltering critical workers in place or replacing the existing distribution system with one based on smaller cities or stockpiles. Detailed planning is likely to uncover some specific difficulties associated with highway-oriented commuting. In this study, it has not been possible to evaluate adequately the potential of commuter rail resources. It is likely that these are a major resource not only for commuting but also for relocation purposes, particularly in the New York and Philadelphia areas. If this should prove to be the case, allocation of space to critical organizations along commuter rail corridors and at line terminals will be a desirable practice.

V ALTERNATIVE POLICIES AND CONSEQUENCES

In this section, a number of more radical modifications of current policies will be discussed and their consequences outlined. No analysis comparable to that laid out in earlier sections has been accorded these alternatives and the discussion of them is intended more to suggest potential approaches than to argue for the adoption of any of them.

A Different Kind of War

The "worst-worst case" aspect of the current risk calculations was commented upon in Section II. We did modify these calculations somewhat by deleting urbanized tentacles from the blast-risk definition and by using summer wind statistics. But we did not tamper with the basic condition that blast risk is to be measured for optimized airbursts whereas fallout risk is to be determined for an all-surface-burst war. This is, of course, an imaginary statement of risks. In the event of an attack, each delivered weapon can be detonated at the surface or in the air but not both. Actually, one would expect the attack to be mixed, with airbursts used against "soft" targets and surface bursts directed at hardened sites. Of course, one can never be sure of this; hence, the current criteria cover any contingency. It is of interest to observe what the consequences would be for crisis relocation in the Northeast Corridor if a more reasonable (and fulfillable) nuclear attack were the basis for planning.

There are very few hardened facilities in the study area. Hence, it would be reasonable to assume that, in the Northeast at least, the detonations would be largely airburst to maximize blast and fire damage. This change would have no effect on the blast-risk situation in the study area since the numbers of persons at blast risk (and their location) are

already based on an airburst war. The fallout-risk situation, however, would change drastically. In effect, no areas would be excluded from hosting the blast-risk population.

The consequences with respect to the feasibility of crisis relocation would be dramatic. For example, the whole coastal area of New Jersey, now denied to relocatees because of assumed fallout risk, would become available. There are, according to our revised criteria of Section IV, some 627,000 persons residing in the fallout-risk area of New Jersey. At a hosting ratio of 5, over 3 million relocatees could be hosted. The best use for this resource would be to relieve the problems uncovered in the New York area. Two major limited-access highways, the New Jersey Turnpike and the Garden State Parkway, and two undivided State highways would allow New Yorkers to relocate to the south. With only a total of seven lanes outbound, however, only about 2 million could actually relocate within a three-day period. By making the limited-access highways one-way south--as they are one-way outbound to the north--the full capacity of New Jersey could be utilized. It will be noted from Appendix 3 that this alternative is all that is needed to make the exodus from New York City meet the three-day goal.

A somewhat more practical and politic relocation plan would leave that part of the New Jersey blast-risk population that is remote from Pennsylvania to be hosted by their neighbors (those in Monmouth and Ocean Counties, for example) and to substitute an equivalent number of New Yorkers to move down the New Jersey and Pennsylvania Turnpikes to host counties in Pennsylvania that are no further than the New York counties used in the current allocation. However the additional hosting capacity is used, it is likely to solve the main question of feasibility left unanswered at this time--how to empty New York City in a three-day period.

Similar gains are apparent in Connecticut, Rhode Island, and Massachusetts. Far fewer persons from this area would need to relocate to the north and pressure on the New York migration would be further relieved. And, of course, if the likelihood of a predominantly airburst attack in the Northeast Corridor was believed to be very high, the problems of providing fallout shelter throughout the area would fade into the background.

Protecting Against Fallout

There is no assurance, of course, that weapons in the urbanized areas would be mainly airburst, even though there are many good reasons for an enemy to use airbursts in preference to surface bursts. Perhaps he is willing to sacrifice some effectiveness against military and industrial targets in order to maximize the loss of life and the difficulties of postattack recovery. Therefore, if the coastal and interior areas of New Jersey and other States were opened up to hosting, it would be a prudent policy to hedge the judgment on the kind of war by continuing--and perhaps emphasizing--preparations to provide high-quality expedient fallout shelter for both hosts and relocatees. Nothing we have encountered in our literature search would suggest that such plans are impractical.

This combination of policies is subject to a quite different interpretation than that just outlined. If one is willing to host relocatees in areas of high fallout risk (if there are many surface bursts) and at the same time plans to provide protection against that very contingency as a matter of prudence, then there is no need to decide what kind of attack is in prospect. Rather, one could argue that the current risk criteria are the best hedge against uncertainty and that they are to be observed <u>except</u> when the purpose of population survival is better served by some modification on a case basis. Thus, planners

ordinarily would not use areas at fallout risk for hosting purposes. If, however, there were a great advantage to be gained by hosting in a particular fallout-risk area, the matter would be decided on its merits. Considering everything, is it worth relocating 3 million people to parts of New Jersey where there might be a severe fallout environment under certain circumstances in order to avoid leaving them in New York city an extra day during a crisis? The answer obviously depends on a number of subjective judgments, but these are not different in kind from others that have entered into the definition of risks in this program.

In sum, the feasibility of crisis relocation in the Northeast Corridor could be affected very significantly either by a revision of the attack concepts underlying the risk calculations or by a policy of selective application of the risk criteria, once the critical aspects of feasibility were understood.

Protecting Against Blast

A parallel line of inquiry is possible with respect to the matter of blast risk. If, for example, fallout-producing surface bursts were judged very likely, one might argue that the blast-risk population ought to be determined by the blast reach for surface bursts. For a single weapon, the surface-burst extent of the 2-psi overpressure is about the same as that of 4 psi for the airburst. And the area covered by at least 4 psi in an airburst is only about half that covered by 2 psi, the current blast-risk criterion. One would be misled, however, if one were to imagine that such a modification to the criteria would reduce the 46 million at blast risk by half.

For one thing, there are many overlapping detonations in a large nuclear attack, such as the one postulated for risk purposes. Changes in the blast-risk criterion can be effective only along the edges of these clusters of weapon detonations. Also, the attack itself is aimed largely against concentrations of population. Consequently, the population density

is relatively low in the outlying areas where changes in blast criteria have their effect. For example, if surface-burst conditions were assumed for air blast calculations, there would be a negligible change in the blast-risk population in the New York City area. The population of all five boroughs and of Nassau County would remain at blast risk. Only 300,000 people in Suffolk County, Long Island, out of the total of 11,300,000 at blast risk would be removed. This result is generally true in the large urban centers. Washington, D.C. is at blast risk for any reasonable criterion.

The same circumstances hold for proposed changes in the overpressure criterion. A change from the current 2-psi criterion to 3 psi, for example, would reduce the 46 million at blast risk in the study area to about 43 million, a reduction of 7 percent. In general, about half of those removed from blast risk could become hosts. The remainder would be located in fallout-risk areas. This swing from relocatee to host has great leverage. The overall hosting ratio in the study area would be about 3. In New England, it would be 4 rather than the ratio of 6 originally described in Section II. As will be noted later, such reductions in average hosting ratio could be of great significance in assessing the feasibility of many aspects of crisis relocation in areas of high population density. For that reason alone, great care and deliberation in defining the blast-risk population to keep it as small as practicable remains an important lesson to be gained from this study. On the other hand, no reasonable modification of the blast-risk criterion will permit New York City to be evacuated in less than four days, as will changes in fallout risk.

Other Housing Solutions

To the extent that housing for the relocated population constitutes the primary measure of hosting feasibility, the situation in the Northeast Corridor leaves the analyst in somewhat of a dilemma. So long as the

current policy of housing relocatees in nonresidential structures is observed, the resource is measured only by a very limited survey. The survey data suggest that, on the average, there are about 100 square feet of usable housing space per host resident but that this congregate-care space is highly variable from county to county and from place to place--from as low as 40 square feet per host to as high as 200 square feet. If hosting ratios typical of the country as a whole were in prospect--say, a ratio of two relocatees for each host--there would be little concern for feasibility. After all, at worst each relocatee would have 20 square feet of living space. However, when the hosting ratio is more than twice as high, as it is in most of the Northeast Corridor, no such flexibility exists.

One alternative that has been considered is to insist that a complete survey of congregate-care resources throughout the host counties be undertaken in advance of any crisis relocation planning in DCPA Regions 1 and 2. The analyzed results of these surveys would permit actual hosting capacity to be substituted in the allocation procedure for the 5 to 1 dummy capacities shown in Appendix 2. Although a relatively reliable way to test feasibility and arrive at credible and workable plans, host area surveys, at least as presently conducted, are costly and time-consuming. The consequent delays in CRP for the Northeast Corridor would be intolerable.

A more promising alternative that is being currently pursued by DCPA is to attempt to develop a predictive method, based on survey results to date, that could be expected to estimate what hosting capacity would be found by survey within an error of less than plus or minus 20 percent. It would be especially important that such a predictive method reliably identify the unusual host counties--those with large deficiencies or large surpluses of congregate-care space relative to the average. It would also be necessary that the method be especially reliable for counties with large populations, since these are attributed

with most of the hosting capacity by an average hosting ratio. Whether a method that meets these rather stringent requirements can be developed is unknown. Hence, it would be prudent to consider yet other alternatives.

One neighbor alternative to those just discussed would be to do some research on a survey method in which the surveyor tabulates the square footage of housing available by consulting county tax records, building inspection records, school board records, and the like rather than through an on-site visit to every facility. A survey of this type, if feasible, would be much less costly and more rapidly implemented. Of course, building-by-building surveys would be needed eventually to assess fallout shelter and to allow detailed utilization planning, but these needs are not those holding up the progress of CRP in densely populated areas.

Alternatives that would relax the need for accurate assessment of resources such as congregate-care housing at high hosting ratios ought to receive serious consideration. The most obvious of these is to exchange the current hosting policy for the one that governed tactical evacuation planning in the 1950s; namely, that relocatees would be housed mainly in residences. This policy is not to be thought of as merely one in which each host family takes in a family from the risk area. After all, there will be five such families relocating for each host family or household. Rather, one needs to consider that there will be one family to a room for practical purposes. The Census has data on dwelling units and numbers of rooms, so assessment of this resource is a trivial problem. More importantly, the resource is large, so that accuracy is not as important as it is under current policy.

The residential alternative may not be politically feasible in peacetime or even during a crisis. The context for the earlier policy was that an attack had been detected; indeed, by the time evacuees reached

safety, the bombs would be raining on the cities. One can believe that host area residents would cooperate in every way in these circumstances. Although cooperation can be predicted in a serious international crisis, this may not be sufficient. There is emergency authority in Federal and State statutes to permit the commandeering of property, including residences. In theory, one could move four out of five host families in with the fifth and allocate five relocating families to each of the vacated premises. In practice, this might be very difficult to do.

A more promising approach would be to consider the use of nonresidential farm structures. This alternative is especially applicable to the Northeast Corridor. The current survey is confined to nonresidential, nonfarm structures. Much of the hosting area in the study area is farmland, some of it among the richest in the world. Traditionally, the barns on these farms are much larger and better kept than the residences and there are equipment sheds and other outbuildings that would provide housing at least as good as that in many warehouses, stores, and industrial plants currently surveyed for congregate-care use. An experimental project to assess on a sampling basis the dimensions of this resource is undoubtedly required and a method must be developed to predict housing capacity from Department of Agriculture and State census data. It would seem, however, that the resource is a large one and that few farm owners would object to intensive use of nonresidential farm structures in a crisis relocation. Combined with nonresidential space in the towns and small cities, the inventory would probably give the flexibility needed to make an allocation on the basis of an average hosting ratio both feasible and credible.

Barring the adoption of one or more of the foregoing, the remaining option that might be considered is to use more fully the hosting resources in the two-Region study area. Because the emphasis in this study has been in part on finding the minimum travel distances that would be required in the Northeast Corridor, there are a few counties

in northern Maine and upstate New York, many more in western New York and Pennsylvania, much of southern Virginia, and nearly all of West Virginia that is simply not used in our final allocation because it is "too far" from the areas at risk. If this concern were to be relaxed, or if a distance-conquering mode of transportation were to be emphasized, the average hosting ratio in the entire study area could be lowered to about 3.5. The need for good information on hosting resources could be reduced accordingly.

Intensive Airlift

The high speed of commercial aircraft makes it feasible to use host areas far beyond tolerable travel distances via ground modes. For example, a 500-mile trip requires only about 30 minutes more flying time than a 250-mile trip. In 1973 the average capacity of aircraft operating out of LaGuardia and John F. Kennedy International Airports in New York was 150 seats. There are now over 300 wide-bodied commercial aircraft in the United States, with seating capacities of 350 to 380 people. The possibility of carrying larger than normal loads is well worth considering. When making short flights, all commercial aircraft have greater weight-carrying capacities than seating capacities. It would be possible to increase passenger loads by about 50 percent if the requirement that all passengers be belted were waived; that is, allowing additional passengers to sit in the aisles during landings and takeoffs would probably not result in unacceptable risks to passengers or aircraft except in bad weather. This was a technique used in the Vietnam airlift.

If wide-bodied commercial aircraft (Boeing 747s, L-1011s, and DC-10s) were used with emergency passenger loads, the two major New York airports could airlift out nearly 1.5 million people over a three-day period. This would make a major contribution to the transportation constraints in the New York area. Perhaps equally important, the opportunity would be presented to more fully utilize hosting capacity not considered in our final allocation.

The major commercial airports in the large risk areas provide excellent bases for the conduct of an emergency airlift. The resources used for normal operations are readily convertible to crisis relocation purposes. Fuel, spares, maintenance, ground service, passenger and baggage facilities, and flight crews are relatively abundant. Airfields in or near the host areas are likely to be the limiting factor in any plans for an intensive airlift, as they were found to be in the analysis of Appendix 3, in which more or less normal capacities were considered.

Commercial airfields in host areas will usually have runways suitable for intermediate commercial jets and will be scaled to a low volume of traffic. Terminal aprons are large enough for only a few aircraft, ground crews are small, and baggage-handling capacity is limited. However, the capacity of most such fields can be increased quickly by airlifting in personnel and equipment from other airports. For example, if it were desired to exploit the capabilities of wide-bodied aircraft, it would be necessary to airlift the appropriate passenger ramps and baggage-handling trucks to the airfields that normally were not serviced by the wide-bodied types. Commercial and Air Force cargo planes and Army cargo and weight-lift helicopters might be organized for this purpose.

Military and former military airfields in host areas might be surveyed for crisis airlift use. A few military airfields have been converted to commercial use or share facilities and runways. An example is the airport at Bangor, Maine. Originally designed for strategic bombers, it can accommodate the heaviest wide-bodied commercial aircraft and has extensive aprons for terminal operations. In the Northeast Corridor, the airports serving Rochester and Buffalo, New York; Erie and Pittsburgh, Pennsylvania; Huntington and Charleston, West Virginia; and Richmond, Virginia could likely be used as potential destinations from which relocatees could be bused to other host areas. Many other host airports may be found suitable upon inspection. Because of the possibility that more intensive use of airlift may relieve host area crowding and speed the exodus from the large cities, a special study of its feasibility appears to be warranted.

VI DEVELOPMENT AND TEST OF PLANNING GUIDANCE

The work done on the feasibility study and certain of its results formed the basis for the preparation of planning guidance for the development of equivalent plans not only in the Northeast Corridor but also in other areas of high population density. The development and test of the guidance was considered as Phase II and III of the effort in accord with the following amendment to the scope of work:

> Article I. Scope of Work is amended by adding the following:
>
> 3. The Contractor, in consultation and cooperation with the Government, shall provide the necessary personnel, facilities, and such other services as may be required to perform the following:
>
> a. Phase II - Based on prior and current studies, including research findings in Phase I of this work unit, develop methodology and guidance for planners to carry out optimal CRP for such areas as the Northeast Corridor.
>
> b. Phase III - Field test the methodology developed in Phase II in an area chosen by the Government.

Accordingly, guidance was developed, based on the experience gained during the course of the feasibility study, reviewed for application in other high-density areas, organized for effective presentation, and ultimately tested in a workshop conducted by the study team at DCPA Region 1, Maynard, MA, during the week of November 8-12, 1976. Based on the results of the workshop, the guidance was revised and submitted to the sponsor separately. In this section, the procedures used in preparing the guidance are summarized, the essence of the guidance is outlined, and the workshop experience reviewed.

Guidance Preparation

During the course of the feasibility study, a number of procedures were developed that would be needed in any comparable planning effort. These included methods for defining a suitable planning region and for subdividing this region into appropriate planning areas, a "general allocation method" for determining relocation flow and approximate travel distances, a "detailed allocation method" for allocating relocatees from specific risk counties to specific host counties within a planning area, guidance materials on transportation resources and capacities, procedures for conducting analyses of "first autos", bus and truck transportation, and non-highway modes, methods for cordon analysis, and ways to adjust risk and host populations, including consideration of relative fallout risk. In some cases, several alternative methods of accomplishing a given planning objective were explored that could or should be used in a formal planning process.

How-to-do-it guidance was prepared for various procedures by those who had developed or used them in the feasibility study. This guidance was reviewed for clarity and unambiguity by other members of the team. In most cases, the methods were applied according to the guidance in the Midwest and California CRP contexts to make sure that the guidance had general application. No attempt was made, of course, to make a complete study of these other planning regions. These applications resulted in examples that were incorporated in the guidance to enrich those available from the Northeast Corridor, and to illustrate special problems that might arise.

Finally, the various procedures had to be incorporated into a stepwise planning process, which included not only the how-to-do-it guidance and examples but also the rationale on why the planning should proceed as proposed. In this respect, the study team had reached the conclusion that the best planning process for this kind or problem would differ

substantially from that employed in doing the feasibility study. In the study, partly because of time constraints and partly because of the exploratory nature of the research, the major parts of the analysis--allocation development, transportation analysis, and risk evaluation--were undertaken concurrently and more-or-less independently. The limitations of this approach have been noted at various points in earlier sections of this report. Although the study of feasibility was not inhibited, it was clear to the study team in retrospect that improved solutions could be obtained if the various aspects of the planning analysis could be integrated and permitted to influence the character of the results throughout the process.

A provisional "interleaving" of the planning procedures was outlined and it was decided to test this approach in the Region 1 workshop. One difficulty was that the examples we had worked out in the feasibility study and concurrent method checking did not reflect fully the order of introduction nor the power of the integrated approach. The working-out of more appropriate examples necessarily had to await the verdict of the workshop experience. Nontheless, the revised approach was used in the workshop with convincing success despite some anomalies in the problem statements and "school solutions."

Following the workshop experience, the planning guidance was organized to reflect the preferred approach and new sample calculations were prepared to exploit the improvements brought to light. The resulting guidance thus reflects fully the insights gained during the research.

Summary of the Guidance

The guidance prepared under this work unit covers the subject matter considered in the feasibility study. As such, it is principally supplemental to Part I of the DCPA CRP guidance, CPG-2-8-A. Whereas the basic guidance emphasizes State-level planning, the proposed guidance emphasizes

interstate or regional planning. Additionally, it bears on some aspects of Part II planning, early risk-area planning, through its analysis of transportation resources for relocation and commuting in very large cities. It does not, however, go into detailed planning for traffic monitoring and control or for organizing to use non-highway modes of transportation. These operational aspects deserve study and guidance development as a supplement to the Part IV guidance in CPG-2-8-D.

The draft guidance is organized into nine sections or chapters in accord with the following outline:

1. Introduction
2. Delineating the Planning Region
3. Preliminary Transportation Analysis
4. Developing Planning Areas
5. Assessing Transportation Capacities
6. Adjusting Risk and Host Populations
7. Detailed Transportation Analysis
8. Detailed Allocation Procedures
9. Documenting the Planning Process

The introduction relates the subject matter to the basic guidance in CPG-2-8-A and CPG-2-8-B and to the situations for which the supplemental guidance is applicable. It introduces the concepts of relocation flow, transportation resources and capacities, and hosting capacities. Finally, it describes the supplemental data package and provides a preview of the planning process.

The second chapter outlines the reasons for defining a planning region comparable to the study area used in this feasibility analysis. The importance of competition among large cities is emphasized and procedures

are presented by which it can be judged which group of States should be considered for interstate planning. Examples are drawn from both the Northeast Corridor and the Midwest. The risk populations are compared with host populations and implications drawn for housing allocations or hosting ratios. Detailed instructions for using risk data are included at the end of the chapter.

The preliminary transportation analysis leads the planner to evaluate the first auto population in each of the large risk areas in the planning region. Attention is also paid to the population requiring other means of transportation. Initial consideration is given to the non-highway modes of transportation, using preliminary capacity factors, to determine the numbers that can be moved and where they might be delivered. The preliminary transportation analysis provides some insight into the dimensions of the first auto movement that constitutes a major load on the available highway system and indicates the degree to which persons without an auto can be relocated by the non-highway modes.

In order to evaluate transportation capacity constraints, it is necessary to subdivide the tentative planning region into suitable planning areas that associate the various large cities with "their" hosting areas. This matter is handled in the fourth section of the guidance. The planner is shown how to choose suitable planning areas so that the anticipated travel distances within adjacent areas are in approximate balance. A major technique used for this purpose is a "general allocation procedure" that approximates the relocation flow and permits estimates of commuting feasibility and average and maximum relocation distances. The planner is shown how to use the general allocation to determine the effect of altering hosting assumptions and how to include important aspects of movement by non-highway modes of transportation.

The assessment of highway capacities in the next section is based on a cordon analysis similar to that in the feasibility study. The planner is shown how to establish one or more cordons for each planning area and

how to use preliminary capacity factors to assess the time required to clear the large cities. Alternatives for increasing capacities are discussed, including use of buses and trucks. The effect of the alternatives is exhibited by examples of several cordon analyses.

Before introducing the final transportation analysis and associated detailed allocation, the matter of adjustment of risk and host populations is introduced. The subject matter follows that in Section III of this report and includes options for adjusting hosting capacities to account for relative fallout risk. The effect of the adjustments is illustrated by a series of general allocations in the New York planning area (Planning Area B of this report). This section concludes with guidance on how to make a final determination of planning area boundaries.

The detailed transportation analysis is based on the population adjustments discussed in the previous section. The planner is introduced to a concept of transportation operating situations (TROS) in which the availability of first autos is matched against the capacity of the relocation system as measured by the time required to clear the large cities. For the various situations, the principal means to be emphasized in the planning are indicated. Within these priorities, emphasis is placed on the need to work with highway, rail, air, and other transportation people to establish better estimates of capacity than the "preliminary" factors given in the guidance. The end result is a best solution for each major risk area that can be used in the detailed allocation and in the planning report.

The detailed allocation procedure introduced in the penultimate section of the guidance is similar to the one used in the feasibility study to produce the allocations of Appendix 2 and the distance information of Table 21. The planner is first taught the procedure using the "20-percent slice" method. This method, which was used in the feasibility study, allocates one-fifth of the risk population of each risk county in turn

beginning with the county most remote from the hosting area and repeats the process until all risk populations have been assigned hosting capacity. The planning guidance also exhibits a "clumping" method in which the risk populations are assigned to contiguous counties in turn after employees of key facilities and dependents have been assigned commuting space. This option is sometimes preferred for policy reasons and may reduce maximum relocation distances in some planning areas. The planner is shown how to accomodate other policy considerations, such as allowing a risk county priority in the use of any hosting space within its boundaries. The guidance also shows how to reflect the results of the transportation analysis in the allocation. For example, hosting capacities of certain counties can be reduced to reflect highway capacities leading to them so that the assignment does not exceed those that could move there. Movement by non-highway modes is also introduced whereby assignments are made for these modes based on location and capacities of airports and rail lines, following which the allocation procedure is used to assign the remaining risk populations via the highway mode. It should be noted that the allocations shown in this report do not reflect these modifications and hence are not to be regarded as a suitable basis for actual planning in the Northeast Corridor.

The final chapter of the guidance describes how the results of the planning process should be documented and presented as the basis for State planning in accord with the basic guidance.

Workshop Experience

The test of the guidance was accomplished during the week of November 8-12, 1976, at the DCPA Regional Operating Center at Maynard, Massachusetts. The form of the test was a workshop in which the participants were asked to perform the planning procedures. The participants consisted of five field officers and specialists from DCPA Region 1, two field officers from DCPA Region 2, and ten State NCP planners, one from each State in Region 1 plus Delaware. Representatives from DCPA Headquarters and Staff College also participated.

A workbook was prepared in advance of the workshop which contained extracts of the guidance material and a series of workshop exercises based on these extracts. The participants were formed into three planning teams. The workbook was distributed one part at a time and one of the members of the study team lectured on the why and how of the guidance before the teams attempted to apply the procedures to assigned problems. A brief review of the workshop experience follows.

On Monday, November 8, following a welcome and description of the intent of the workshop, the teams were formed and a general overview provided of the guidance as it would be presented. Thereafter, Section 2 of the workbook was distributed and discussed. The teams were asked to apply the procedures for delineating a planning region beginning with New York, Chicago, and Dallas, respectively. The results of the map exercise were discussed and the use of the computer printout and DCPA TR-82 in reviewing the hosting situation presented. One team applied the procedures to the Northeast using the printout, the second used TR-82 in the same area, and the third used TR-82 in the Midwest region.

After lunch on Monday, the preliminary transportation analysis was described and the teams performed an analysis of first autos and carless persons in Boston, New York, and Philadelphia, respectively. Thereafter, the subdivision of the Northeast planning region into planning areas was discussed and the procedures carried out. The session concluded with the setting up of the worksheets for performing a general allocation in the Boston, New York, and Philadelphia planning areas.

On Tuesday, November 9, the teams each performed a general allocation and the results were discussed. Thereafter, the procedures and background for a highway capacity analysis were discussed and the teams performed an analysis in their assigned planning area. After lunch, the concept of transportation operating situations was introduced and discussed and the non-highway modes of transportation reviewed in detail.

On Wednesday, November 10, the procedure for adjusting the blast risk population was discussed and the teams performed another general allocation in their assigned planning areas and compared the results with the unadjusted case. Thereafter, there was a review session on the final analysis of transportation options and an appropriate exercise. In the final session of the day, two teams were lectured on congregate-care capacities and their estimation where surveys were not complete while the third team prepared a mileage table for their planning area for use in a detailed allocation.

On Thursday morning, November 11, two teams followed the procedure for preparing a mileage table while the third team received the session on congregate-care capacity. Thereafter, the matter of adjustments based on relative fallout risk was introduced and discussed. After lunch, each team performed a detailed allocation with some variation from previously prepared general allocations. Team 1 used adjusted risk populations. Team 2 employed simulated survey data for host county capacities in lieu of a hosting ratio. Team 3 adjusted host capacities based on relative fallout risk.

On Friday morning, November 12, a debriefing session was held in which participants were free to comment on any and all aspects of the guidance and the associated CRP problems. There was an extended and animated discussion by the participants that was generally supportive of the guidance and the organization of the parts. This and all other discussions during the workshop were taped and reviewed later in the revision of the guidance material.

It is the opinion of the study team that the workshop was very successful in achieving its purpose and that the resulting guidance can be effective for crisis relocation planning in highly urbanized areas. In addition to proving out a more flexible and effective planning process

than that actually employed in the feasibility study, a number of procedural errors and ambiguities were uncovered and corrected. The opportunity to deal directly with a representative group of users has permitted considerable improvement in the presentation of the guidance.

VII CONCLUSIONS AND RECOMMENDATIONS

The work reported herein mainly represents our analysis of the feasibility of crisis relocation in the Northeast Corridor. The results also form the basis for the preparation of planning guidance for the development of regional plans not only in the Northeast Corridor but also in other areas of high population density, such as the Detroit-Chicago-St. Louis area and the State of California. With this in mind, our conclusions and recommendations apply both to the questions of feasibility and to the characteristics of the planning guidance.

Conclusions

- Relocation of the blast-risk population of DCPA Regions 1 and 2 to safer areas at a reasonable travel distance from the risk areas is feasible if the peacetime emergency housing allotment of 40 square feet per person is reduced to 20 square feet per person in nonresidential structures (a hosting ratio of five, on the average).

- An allocation at the above space allotment results in an average relocation distance of 97 miles for the study area (less West Virginia) and a maximum travel distance of not more than 288 miles. For an allocation that attempts to minimize travel distances, relocatees are not assigned from other States to West Virginia (except for three panhandle counties in the Shenandoah Valley) and there is much unused hosting area in southern Virginia, northern Maine, and western New York State.

- A hand procedure for allocating blast-risk population from many competing risk areas to limited hosting resources in an equitable fashion has been developed. This method could be automated. Although oriented toward the highway mode of travel, it can be used to incorporate other modes of transportation.

- At the hosting ratio needed in the study area, actual plans, including the basic interstate allocation, will be sensitive to the distribution of congregate-care space among host counties. Results of a host-area survey, adjusted to a space criterion of 20 square feet per relocatee, or a

reliable prediction of such results will be required to permit planning of crisis relocation in the study area unless the general availability of housing for relocatees is at least doubled by policy changes, such as use of residences or nonresidential farm structures.

- Relocation distances, both average and maximum, are sensitive to the definition of risk populations. Elimination of "urbanized tentacles" and evaluation of fallout risk at the MCD level resulted in a 10 percent reduction in travel distances.

- The capacity of the existing highway system, particularly in the vicinity of the risk areas of over a million population, determines the time scale of a crisis relocation in the Northeast Corridor. Under our capacity assumptions, it is not possible to empty the large areas in a period of three days unless limited-access highways are made one-way outbound. Even so, four days would be required to evacuate New York City. Because our cordon analysis is believed to be conservative, a more detailed movement analysis may result in some reduction in the length of the movement period, especially in the New York area.

- The general feasibility of relocation within a three-day period is highly sensitive to the risk criteria. The assumption of surface bursts for fallout risk is the most critical criterion. If the nonrisk parts of New Jersey were made available for hosting, it appears that New York City could be emptied within three days. Movement time is less sensitive to the blast-risk criterion, provided care is exercised to minimize the number of persons who must be relocated by rigorous application of the overpressure criterion.

- Commuting of essential workers to the risk areas to maintain operations in support of the population or of national defense appears to be feasible, provided that the number of such workers is restricted to less than 8 percent of the population and that they work in at least two 12-hour shifts. Commuting distances--average 42 miles, maximum 79 miles--are sensitive to the details of risk definition, such as elimination of urbanized tentacles and use of MCD fallout-risk data, in the vicinity of the large metropolitan areas. Commuting periods for full shifts will be up to three times longer than normal in some key areas, requiring the staggering of working hours.

- Maximum use of nonhighway modes of transportation by those without access to an automobile will be necessary to minimize added stress on the highway system. The operational aspects of such use need study.

- Under the all-surface-burst assumption, high-quality fallout protection (PF greater than 40) will be required in a large part of the study area. Consequently, construction of expedient shelters will need emphasis rather than the upgrading of existing buildings. The amount of high-quality shelter needed can be reduced substantially by assigning the blast-risk population preferentially to host areas at the least fallout risk at the price of a 10 percent increase in relocation distances.

Recommendations

- The allocation given in Appendix 2 should be used in lieu of the ADAGIO printout as the starting point for inter-state planning in the Northeast Corridor pending the availability of better data on congregate-care capacity or changes in current policy affecting hosting. It should, however, be regarded merely as a starting point in conjunction with the draft planning guidance.

- Efforts to develop an adequate method for predicting congregate-care capacity and to develop a simplified survey method should be accelerated.

- The portions of limited-access (and other) highways that should be planned for conversion to one-way *outbound* should be identified by a detailed movement analysis and operational planning initiated for such conversion as a basic element of CRP in the Northeast Corridor.

- A special study should be made of crisis relocation from the New York City area, with emphasis on a detailed transportation analysis.

- The adjustments in risk criteria made in this analysis should be adopted and studies underway completed to evaluate alternative risk assumptions.

- The results of this study and the planning guidance based on it should be applied to the potential relocation problems in other areas of high population density.

- Studies should be initiated to form the basis for additional planning guidance on the operational aspects of traffic control and use of air, rail, and water transport for incorporation into operational plans for large cities.

The information in this Appendix is provided for documentation purposes. The four-element method described should not be used for operational predictions. A more reliable technique is described in:

Walmer E. Strope and Betty J. Neitzel, Prediction of Congregate-Care Space in Nonmetropolitan Counties, Stanford Research Institute, (February, 1977)

APPENDIX 1

METHODS OF ESTIMATING CONGREGATE CARE SPACE USING READILY AVAILABLE CENSUS DATA

METHODS OF ESTIMATING CONGREGATE CARE SPACE
USING READILY AVAILABLE CENSUS DATA

For planning purposes it would be convenient to be able to make estimates of congregate care capacity in potential host area counties prior to making actual surveys: such estimating methods would allow the planning of efficient field surveys, save expense by limiting survey areas, and allow other relocation planning to proceed simultaneously. Useful estimating methods should be based on information readily available to State and regional planners, such as census information. The estimating method should also be easy for the planner to understand and use. An analysis of the 1974 survey results[5] determined that the data did not permit a satisfactory method for estimating county congregate care capacity to be developed.

The number of congregate care spaces per resident for the 28 counties studied ranged from a high of eight to a low of just under two spaces per county resident: the average value was 3.692. Linear regression analysis showed promise of being able to develop a method to predict congregate care capacities for such facilities as schools and retail establishments on the basis of data available in the Bureau of the Census County and City Data Book,[20] a source readily available to planners. Information available for other facilities such as hotels and motels showed less promise as appropriate data for prediction of capacity. The final report suggests that prediction methods can be improved as additional survey data becomes available.

This paper describes an effort to improve predictive techniques, accomplished as part of the feasibility study.

Approach

Analysis of the 1974 host area survey data shows that some 20 survey use class codes account for over 97 percent of the space found (Ref. 5, Table 15). Commercial facilities (food and other stores, auto sales, restaurants, cafeterias, and bars, etc.) comprise almost 30 percent of the space. Manufacturing facilities account for 8 percent, and schools, colleges, and the like make up about 20 percent, churches 5 percent, and so on. Census information in the County and City Data Book (CCDB) corresponds in varying degrees to these categories or to groups of categories. Four divisions of the survey data were chosen for test to see if census information could be used to develop accurate predictions of spaces in each of the divisions.

The host area survey use class codes that constitute each group and their corresponding CCDB information sources are given in Table 1. Certain spaces that are not population-, institutional-, commercial-, or industrial-, oriented have been eliminated, but these are a relatively minor proportion of the total spaces in most counties.

Data Base

Certain revisions in the 1974 host area survey data made in the course of the first analysis are continued in this research, and further changes are made to adjust the data base for this effort. The county total spaces, totals for host areas, and use class code totals that appear on DCPA tabulations differ from county and host area (or State) totals used here. The reasons are:

1. Since we are concerned here with estimating on a county basis, those counties for which survey data is incomplete because part of the county is in the risk area or for other reasons are eliminated. This leaves a data base of 28 counties of the 47 in which surveys were made.

2. Reclassification of the survey data and new use class codes introduced in the first analysis are continued in this phase.

Table 1

HOST AREA SURVEY USE CLASS CODES AND CORRESPONDING CENSUS INFORMATION

Group/Use Class Code	County and City Data Book References
Population oriented spaces	
10. Residential (except 12)	Table 2, counties, column 3 1970 total population
20. Educational (except 25)	
30. Religious (except 32)	
40. Government and public service (except 46)	
70. Amusement/meeting	
Institutional population spaces	
12. Dormitory/barracks	Table 2, counties, column 16, percentage living in group quarters x column 3, total population
25. Correctional schools	
32. Retreat/monastery/convent	
46. Jails/prisons/correctional institutions	
Commercial spaces	
50. Commercial	Table 2, counties, column 135, retail sales 1967, all establishments
80. Transportation	
Industrial spaces	
60. Industrial	Table 2, counties, column 124, manufactures, 1967, all employees, annual average

3. Since the emphasis of this effort is to relate congregate care spaces to activities or characteristics of counties, a minor number of spaces in facilities listed as "unidentified" in the 1974 survey have been eliminated. More important, spaces which cannot be predicted by the independent variables chosen have been eliminated. These include highway culverts in Arizona, mines in Colorado and Montana, a large utility project tunnel in Northfield, Franklin County, Massachusetts, and so on. The most seriously affected county is Cochise, Arizona, where almost 30 percent of the spaces are eliminated by removing some 19,000 spaces in highway culverts and 49,000 spaces at Fort Huachuca for which no predictors were found.*

Method of Analysis

The basic statistics, means, standard deviations, and correlation coefficients were developed for each of the four data sets to see if the relationships between the components of each of the four data sets are sufficiently interdependent that census data can be used to predict spaces. Linear regressions were run for each set, and the resulting formulas for each set were used to estimate congregate care spaces.

The method developed is referred to in the rest of this paper as the "four element method", since it combines the calculations for the four divisions of use class codes. Calculations are based on the linear regression formula for each of the divisions. They are:

cc spaces in public buildings = 622.70 + 1.53 x county population

cc spaces in group quarters = 1270.27 + 2.17 x county population in group quarters

cc spaces in commercial buildings = -695.65 + 1.11 x county total retail sales in thousands of dollars

cc spaces in industrial buildings = 2416.98 + 3.06 x total manufacturing employees in the county.

---

* Note that this is not to say that the spaces are non-existent or not useful to the planner, but that they are not compatible with this particular analysis.

These calculations are summed to produce the total county estimate.

If factors providing valid relationships between the four independent variables (population, population in group quarters, retail sales, and manufacturing employment), and the number of congregate care spaces in the facilities they represent can be developed, a relatively simple work sheet can be constructed for the use of State and regional planners. The form would list the source of data required from the County and City Data Book by table and column. Factors for each of the independent variables would be listed in the appropriate columns. Directions for the simple calculations to be performed would be included. Figure 1 is an example of such a work sheet.

Summary of Results

In the first analysis of the 1974 host area survey, estimates of county congregate care spaces were made using the regression formula ccs = -3934 + (3.79 x population) (Reference 5, pp. 36-37 show results of this calculation). Comparisons of the seven State totals for which estimates were made with the results of estimates made using the four element method disclose that estimates for four States were improved and three degraded. Improvements were more striking than losses in accuracy, ranging from 2 percent to 25 percent for improvements. Degraded estimates were 3 percent to 10 percent less accurate when the four element method was used.

Comparison of the two estimating methods for the 28 county sample shows that estimates for 18 counties were improved, and 10 counties degraded. The new method shows a decrease in very large errors (over 50 percent). Figure 2 summarizes percentage error in the two estimating methods.

Figure 1

HOST AREA CONGREGATE CARE SPACE ESTIMATE

WORK SHEET

RISK AREA:______________

Facilities	Public Buildings		Group Quarters			Commercial Bldgs		Industrial Bldgs		Total Spaces
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
----	Population	Spaces	Pop. in G.Q,%	Pop. in G.Q.,no	Spaces	Retail Sales	Spaces	Mfg. Employer	Spaces	----
CCDB Reference,Table 2	Col. 3	----	Col. 9	----	----	Col. 135	----	Col. 124	----	----
Calculation		(1)x1.53		(1)x(3)	(4)x2.17		(6)x1.11		(8)x3.06	(2)+(5)+(7)+(9)
County Name										

DIRECTIONS:

Col. 1. Enter Total Population CCDB Table 2, Col.3

Col. 2. Multiply Col. 1 by 1.53 and Enter Results in Col. 2

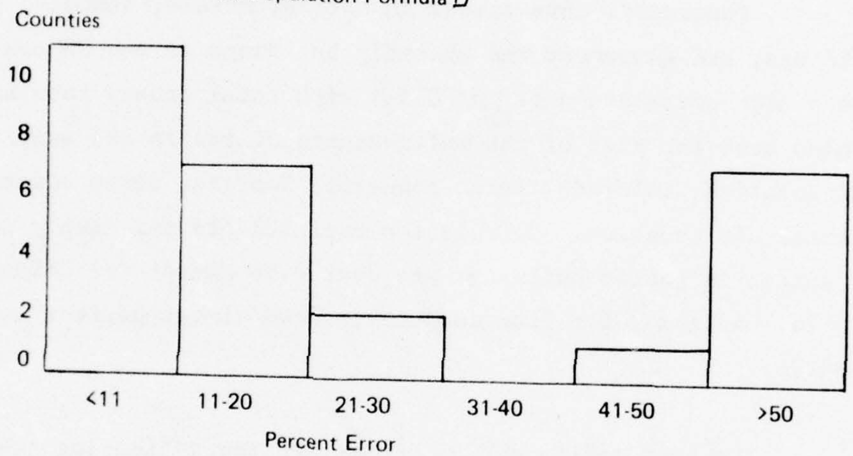
Col. 3. Enter Population in Group Quarters, CCDB Table 2, Col. 9 (%)

Col. 4. Multiply Col. 1 by Col. 3, Enter in Col. 4

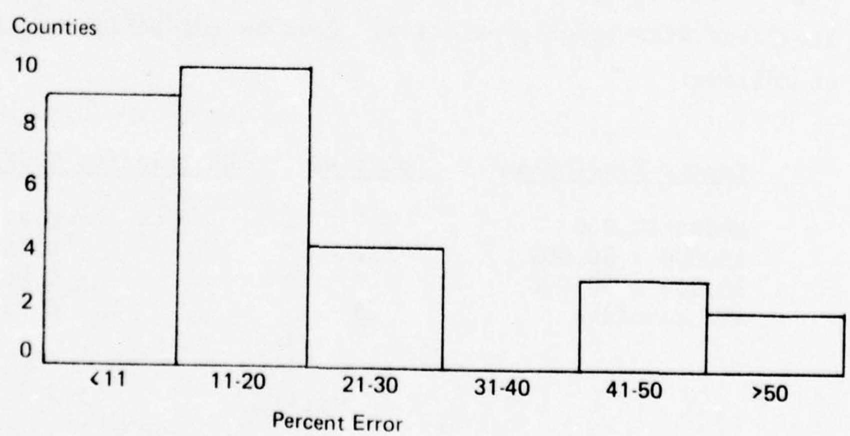
etc. etc.

Figure 2
COMPARISON OF TWO METHODS
OF ESTIMATING COUNTY CONGREGATE
CARE SPACES

Errors in Estimates Based
on Population Formula 1/



Errors in Estimates Based
on Four Element Method



1/ Ref. 5, Table 14

Discussion of the Four Element Method

This section is concerned with detailed discussion of the characteristics of the four estimating elements: public buildings, group quarters, commercial buildings, and manufacturing facilities. The host area survey use class codes included in each of the elements are given in Table 1.

Congregate Care Spaces in Public Buildings

Congregate care spaces in hotels, motels, schools, government buildings, and amusement and assembly buildings in the 28 county sample have a high correlation (r_{xy} of 0.96) with total county population. This is also true for most of the multi-county States in the sample: Arizona, four counties; Colorado, seven counties; Georgia, eight counties; and Montana, six counties. Correlation coefficients for county population and spaces in public buildings are over 0.90 except for Colorado, which is 0.76. Arizona, for four counties, shows almost perfect correlation (0.99876).

Further refinement of the method for estimating public building spaces was attempted by ranking counties by size of population to test correlations within size groupings. Results are negative: correlations are high for the larger counties (20,000 to 80,000 population) and decrease for groupings with lower population. Results for public building spaces are as follows:

County Population	Counties	Correlation Coefficient, r_{xy}
Under 10,000	9	0.21
10,000 - 20,000	12	0.75
20,000 - 80,000	7	0.96
All counties	28	0.96

Congregate Care Spaces in Group Quarters

Host area survey results for 1974 locate group quarter congregate care spaces (in dormitories, barracks, monasteries and convents, correctional schools, jails and prisons) in 22 counties. These data were compared with 1970 population living in group quarters (CCDB, Table 2, Column 16). The comparisons show low correlation (r^2=0.26) and hence an unreliable estimating coefficient. Subsequent test of the coefficient by its use as a multiplier of the census information for each county and comparison with host area survey results bears out this observation.

Congregate Care Spaces in Commercial Buildings

The correlation of spaces found in commercial facilities in the 1974 host area survey correlates closely with retail sales in the county in which spaces were found. Survey spaces are those in use class categories 5x, commercial, with the addition of spaces in automobile sales, service, and repair from category 8x, transportation. The correlation coefficient 0.98 indicates a stable relationship between total retail sales (CCDB, Table 2, Column 135) and congregate care spaces in the county.

Patterns within the States are comparable to the overall pattern. Correlation coefficients and coefficient of determination for the four multi-county States in the sample are:

State	No. Counties	Coefficient of Correlation	Coefficient of Determination
Arizona	4	0.99	0.99
Colorado	7	0.96	0.93
Georgia	8	0.99	0.98
Montana	6	0.99	0.98

The correlation of commercial spaces and sales for county population size is similar to that for the public building spaces-population

series, but with better correlation in the 10,000 - 20,000 group. Correlation coefficients are:

County Population	No. of Counties	Correlation Coefficient
Under 10,000	9	0.26
10,000 - 20,000	12	0.91
20,000 - 80,000	7	0.97
All counties	28	0.98

On the basis of these statistics, the linear regression formula represents an adequate means for estimating commercial spaces, and is stable over a wide range of county population sizes.

Spaces in Industrial Buildings

The County and City Data Book provides three statistics on manufacturing industries that can be matched with congregate care spaces in manufacturing facilities: value added by manufacture, payroll, and manufacturing employment. The latter, total manufacturing employees (CCDB, Table 2, Column 124) has the highest correlation with spaces in manufacturing facilities listed in the 1974 host area survey, and was used for this research. However, because of the low coefficient of determination (r^2=0.61), the regression coefficient is not an adequate measure for estimating care spaces.

The use of manufacturing data has further disadvantages. When there are only a few establishments engaged in manufacturing in a county, data are often withheld from the CCDB (and other census sources) to prevent disclosure of confidential information. For this and other reasons, CCDB showed no manufacturing employment in 9 of the 28 counties in the sample. In two counties, no spaces were found in manufacturing facilities by the host area survey. In the other seven counties, the spaces found in industrial facilities by the survey are a minor fraction of the total county spaces (mostly under 1 percent) except for Teller County, Colorado,

where 1512 spaces in manufacturing use class codes constitute 6.29 percent of total county spaces. CCDB does not include employment data for manufacturing in Teller County, so no estimate could be made.

Sources of Error in Four Element Estimating Method

The range of errors for county estimates are from 0.02 percent (Monroe County, Georgia) to 67 percent in Wilkinson County, also in Georgia. Figure 3 gives some insight into the elements that contribute most to overall error. Estimates of total spaces in the 28 counties show that 19 of the counties were estimated within 20 percent of their actuals. The most stable of the four elements, public buildings and commercial building estimates are within 20 percent for 15 and 16 of the 28 counties respectively, but four counties (commercial buildings) and six counties (public buildings) were over 50 percent in error. Group quarters and industrial building space estimates predicted as unstable by their low correlation coefficients show over half of the estimates are over 50 percent in error. Note also that estimates could not be made for all counties because of lack of census information, or no comparisons could be made because no spaces in group quarters or industrial buildings are recorded in the 1974 survey, although census information indicated the presence of such facilities in the county.

As indicated by the correlations of county population and congregate care spaces in public and commercial buildings for the several size groups (populations under 10,000, 10,000 to 20,000, and over 20,000, larger errors occur in the smaller counties. No pattern of errors has been found that would help to develop more precise estimating formulae. Error distribution for county population size groups is illustrated in Figures 4, 5, and 6 for total estimating error and for public and commercial building estimates.

Figure 3: PERCENT ERROR IN COUNTY C.C. SPACE ESTIMATES
MADE USING THE FOUR ELEMENT METHOD
(Est. vs. 1974 H.A. Survey)

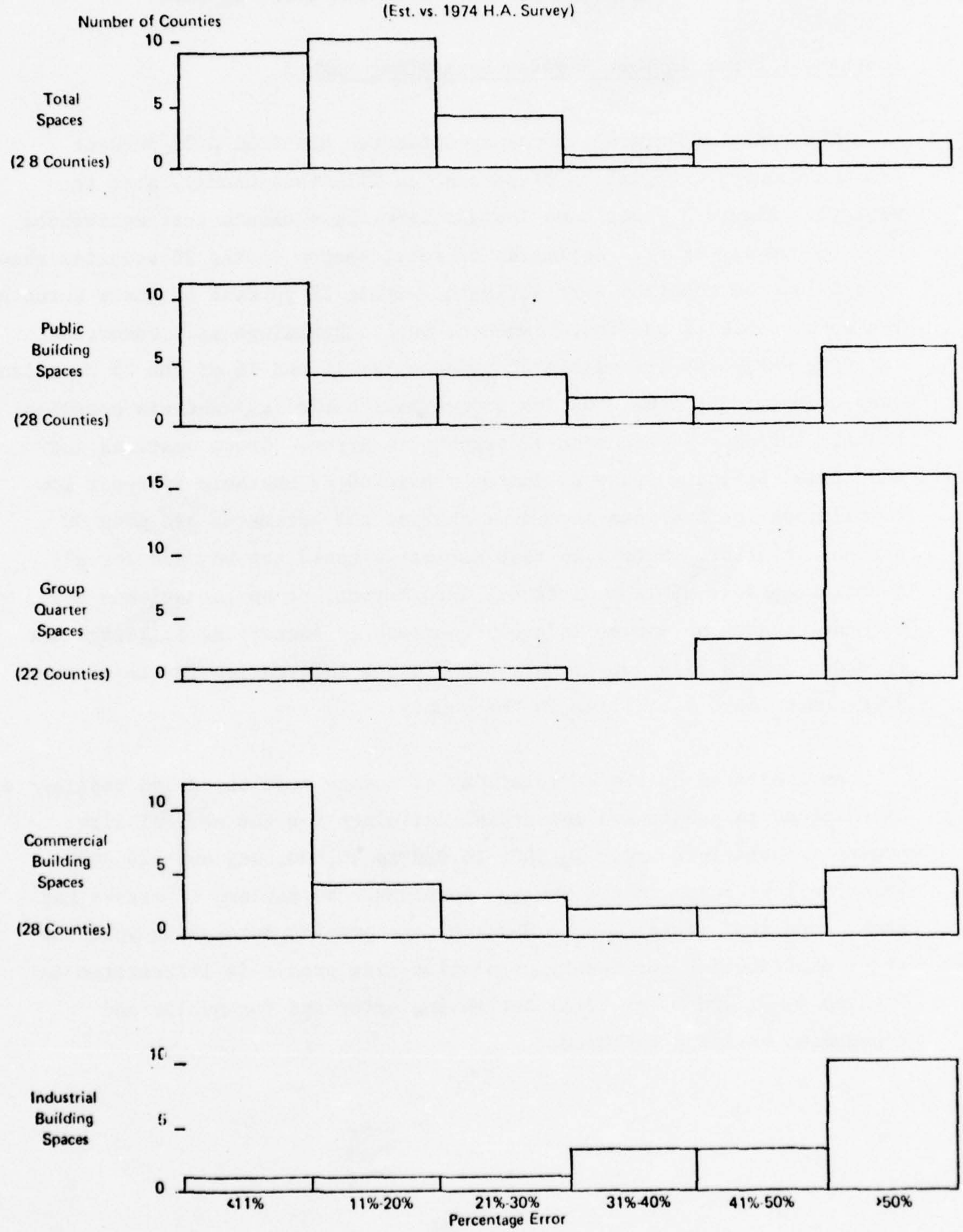


Figure 4
PERCENT ERROR IN TOTAL COUNTY
CONGREGATE CARE SPACE ESTIMATES
(All Counties and 3 Population Size Groups)

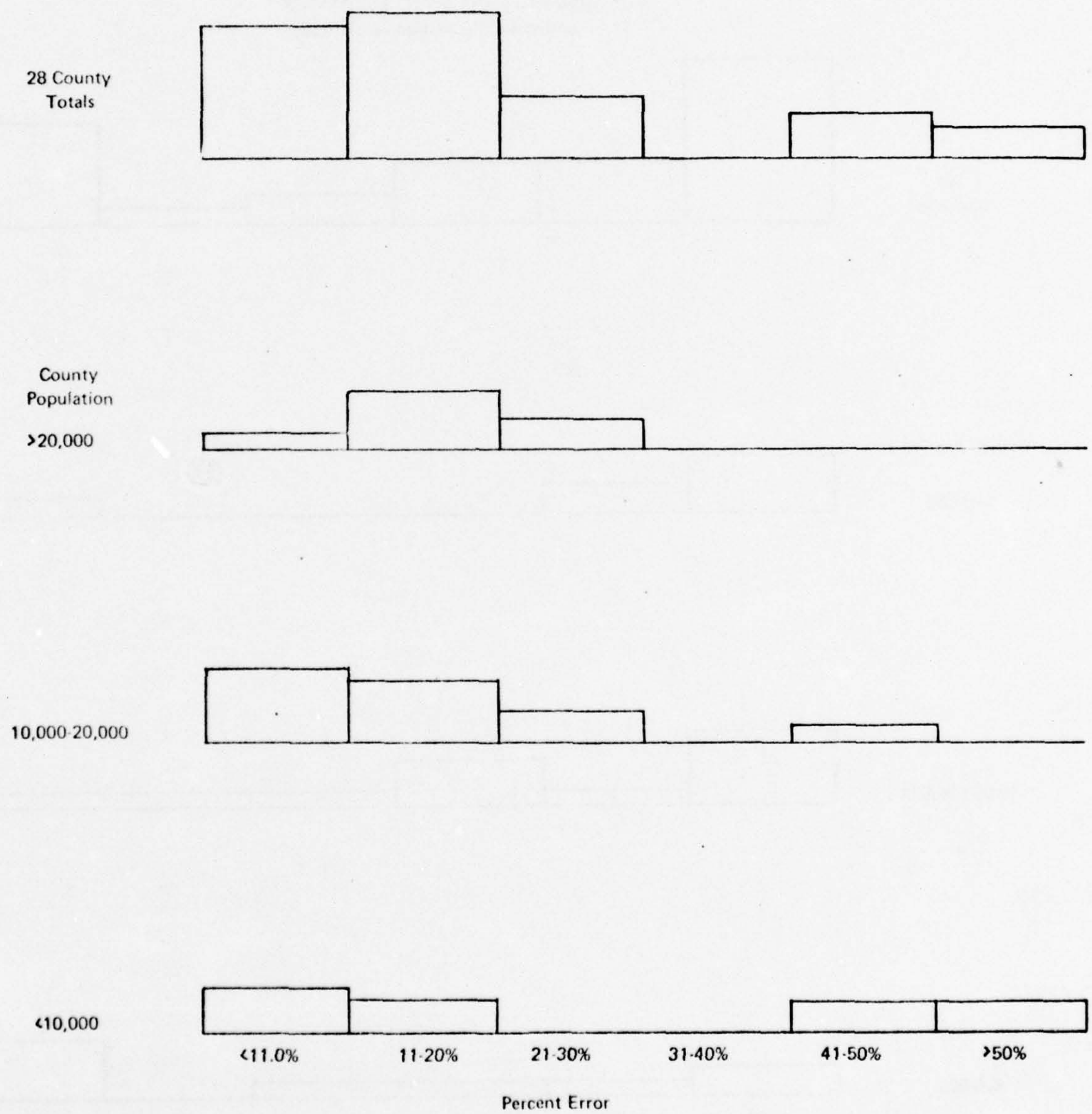


Figure 5
PERCENT ERORR IN PUBLIC BUILDING
CONGREGATE CARE SPACE ESTIMATES
(All Counties and Population Size Groups)

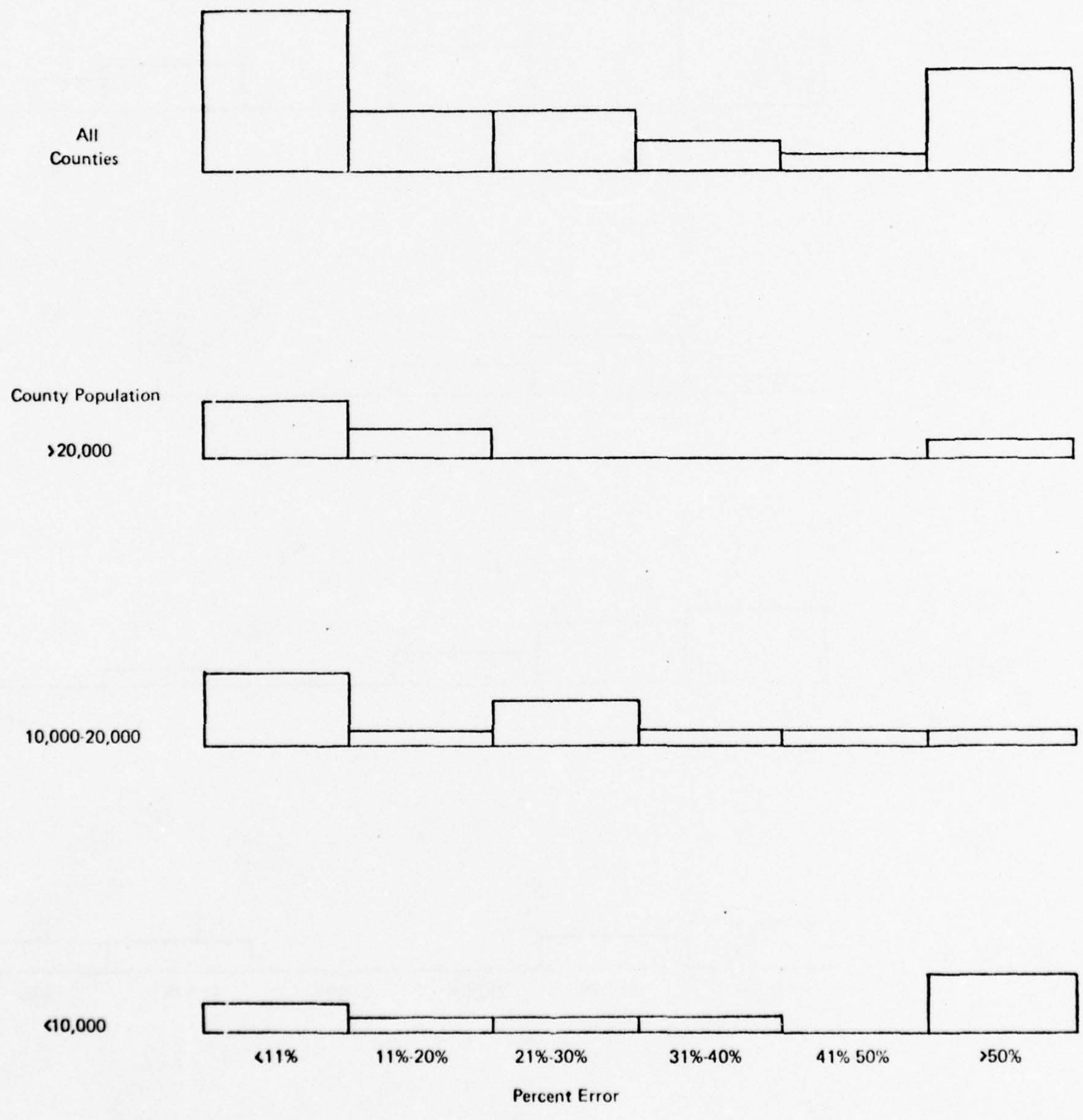
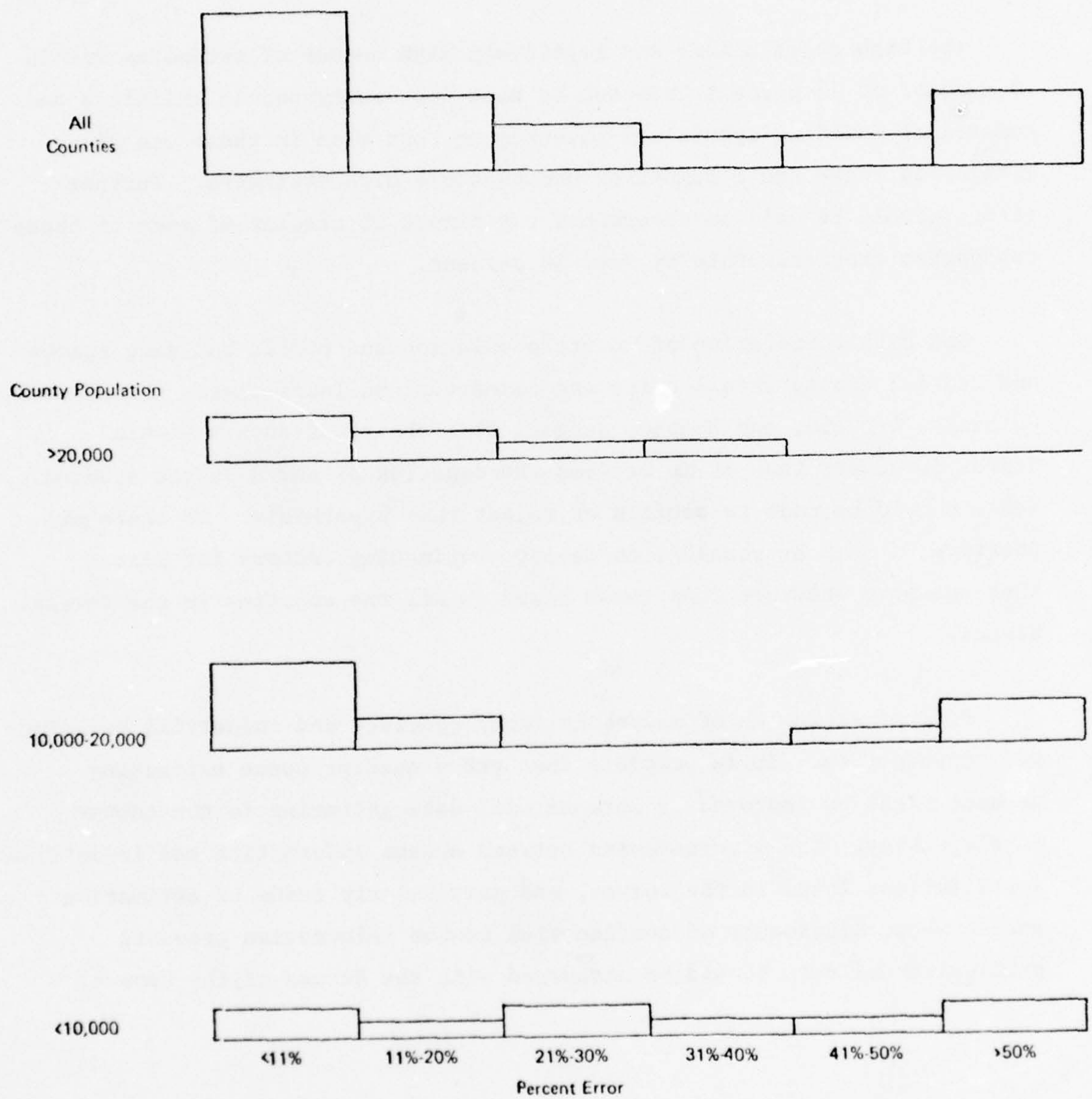


Figure 6
PERCENT ERROR IN COMMERCIAL BUILDING
CONGREGATE CARE SPACE ESTIMATES
(All Counties and Population Size Groups)



Conclusions and Recommendations

Although the four element estimating method shows some improvement over the per capita method of estimating total congregate care spaces, its use can lead to unacceptable errors.

The high correlations and relatively high number of estimates within 10 percent or 20 percent that can be made for county public buildings and commercial building spaces are encouraging, but even in these use class categories there are a number of unacceptable high estimates. Further effort should be made to understand why almost 50 percent of each of these categories are inaccurate by over 30 percent.

The high correlation of county population and public building spaces and between county retail sales and commercial building spaces for Arizona, Colorado, Georgia, and Montana suggest that the relationship within States is closer than it is between the counties of seven States studied. Tests should be made to confirm or reject this hypothesis. If tests are positive, it may be possible to develop estimating factors for States that are more accurate than those based on all the counties in the several States.

Present estimates of spaces in group quarters and industrial buildings are unacceptable. It is possible that group quarter space estimating methods might be improved by more careful data gathering in the course of the survey. The discrepancies between census information and industrial installations found in the survey, and particularly means of estimating spaces where disclosure of confidential census information prevents publication of data should be discussed with the Bureau of the Census.

APPENDIX 2

FINAL ALLOCATION

PLANNING AREA A1 -- EASTERN NEW ENGLAND (Page 1 of 2)

Host County	Capacity	New London CT	Washington RI	Newport RI	Kent RI	Bristol RI	Providence RI	Nantucket MA	Barnstable MA	Bristol MA	Plymouth MA	Norfolk MA	Middlesex MA	Suffolk MA	Worcester MA	Essex MA	Hillsborough NH	Rockingham NH
Risk Population		148.7	52.4	91.8	142.4	45.9	581.5	3.8	19.2	444.3	218.3	590.5	1300.0	735.2	584.9	554.3	188.6	93.1
20 Percent Slice		29.7	10.5	18.4	28.5	9.2	116.3	0.8	3.8	88.9	43.7	118.1	260.0	147.0	117.0	110.9	37.7	18.6
New London CT	24.8	24.8																
Washington RI	147.7	4.9	10.5	6.5	28.5	9.2	88.1											
Newport RI	11.9			11.9														
Dukes MA	30.6							3.8										
Barnstable MA	387.5				8.5	9.2	21.7		3.8	88.9		108.4		147.0				
Plymouth MA	150.5	29.7	10.5	18.4	20.0		28.2				43.7							
Worcester MA	37.2														37.2			
Hillsborough NH	157.4						39.9								79.8		37.7	
Cheshire NH	261.8									88.9		118.1	54.8					
Rockingham NH	28.3											9.7						18.6
Strafford NH	188.7								3.8		43.7		23.8			110.9		
Merrimack NH	376.8												279.6	96.1				
Sullivan NH	154.7	29.7	6.9												117.0			
Belknap NH	161.8												161.8					
Carroll NH	92.7													60.1	32.6			
Grafton NH	274.6											118.1	156.5					
Coos NH	171.5	2.7					57.9									110.9		
York ME	439.4	3.3	3.6	18.4	28.5	9.2	147.1							50.9		110.9	37.7	18.6
Cumberland ME	197.8						23.9		3.8	88.9	43.7		6.9					
Sagadahoc ME	38.6	27.0											8.5					
Androscoggin ME	101.1													86.9				
Oxford ME	217.3												72.6	34.8	109.9			
Lincoln ME	102.7		10.5	18.4	28.5	9.2	6.3											18.6
Knox ME	145.1															110.9		18.6
Kennebec ME	476.2						52.1		3.8	88.9	43.7	118.1	169.6					
Waldo ME	116.6						32.2		4.0			80.4						
Franklin ME	112.2													112.2				
Hancock ME	167.1												128.9	40.0				
Somerset ME	203.0	6.0	10.4	18.2	28.4	9.1	84.1											
Washington ME	149.3																	18.7
Penobscot ME	358.0										43.5			107.2	116.9	67.2	12.4	
Piscataquis ME	81.4															43.5	25.4	
Aroostook ME	412.2																	

PLANNING AREA A1 -- EASTERN NEW ENGLAND (Page 2 of 2)

		New London CT	Bristol MA	Norfolk MA	Middlesex MA	Worcester MA	Hillsborough NH	Merrimack NH	Strafford NH	York ME	Cumberland ME	Sagadahoc ME	Androscoggin ME	Hancock ME	Penobscot ME	Aroostook ME
Risk Population		148.7	444.3	590.5	1300.0	584.9	188.6	5.6	32.7	23.7	153.0	15.7	71.1	1.2	53.8	11.6
20 Percent Slice		29.7	88.9	118.1	260.0	117.0	37.7	1.1	6.5	4.7	30.6	3.1	14.2	0.2	10.8	2.3
Host County	Capacity															
Strafford NH	188.7								6.5							
Merrimack NH	376.8							1.1								
Sullivan NH	154.7							1.1								
York ME	439.4								6.5	4.7						
Cumberland ME	197.8										30.6					
Sagadahoc ME	38.6											3.1				
Androscoggin ME	101.1												14.2			
Lincoln ME	102.7								6.5	4.7						
Knox ME	145.1								6.5	4.7	4.4					
Hancock ME	167.1													0.2		
Somerset ME	203.0										26.2	6.4	14.2			
Washington ME	149.3								6.7	4.9	85.2	3.1	28.5	1.0		
Penobscot ME	358.0														10.8	
Piscataquis ME	81.4							1.2		4.7	6.6					
Aroostook ME	412.2											3.1	14.2		43.0	11.6
Orange VT	88.4				88.4											
Caledonia VT	113.9					84.4	29.5									
Essex VT	27.1				17.8		8.2	1.1								
Orleans VT	100.8		88.7	12.1												
Lamoille VT	66.5	20.6				7.1	37.7	1.1								
Franklin VT	156.4			25.6	130.8											

PLANNING AREA A2 -- WESTERN NEW ENGLAND

		Fairfield CT	New Haven CT	Middlesex CT	Litchfield CT	Hartford CT	Tolland CT	Hampden MA	Hampshire MA	Berkshire MA	Chittenden VT
Risk Population		750.3	744.9	71.3	94.3	815.4	79.2	456.1	80.3	80.4	83.1
20 Percent Slice		150.1	149.0	14.3	18.9	163.1	15.8	91.2	16.1	16.1	16.6
Host County	Capacity										
Fairfield CT	212.5	150.1	62.4								
Litchfield CT	249.1		86.6	14.3	18.9	129.3					
Hartford CT	6.5					6.5					
Hampden MA	15.0							15.0			
Hampshire MA	218.3		82.9			27.3	15.8	76.2	16.1		
Berkshire MA	344.8	229.4	66.1	14.3	18.9					16.1	
Franklin MA	296.0			9.8		163.1	15.8	91.2	16.1		
Bennington VT	146.4	70.8	75.6								
Windham VT	165.4		73.4	4.5	18.9	52.8	15.8				
Rutland VT	263.2	120.2	128.7	14.3							
Windsor VT	220.4		20.3		18.9	163.1	15.8			2.3	
Addison VT	121.3							91.2	16.1	13.8	
Washington VT	238.3		62.3	14.3	18.9	142.8					
Chittenden VT	80.2		63.6								16.6
Grand Isle VT	17.9						15.8	2.1			
Washington NY	263.6	29.9				110.3		91.2	16.1	16.1	
Essex NY	173.2	150.1	23.1								
Clinton NY	94.8					20.3		74.5			
Franklin NY	210.5							14.6	16.1	32.2	66.5
St. Laurence NY	404.8		NOT USED								

PLANNING AREA B -- NEW YORK STATE (Page 1 of 2)

Host County	Capacity	Suffolk	Richmond	Kings	Nassau	Queens	New York	Bronx	Westchester	Rockland	Albany	Rensselaer	Schenectady	Onondaga	Monroe	Erie
Risk Population		1061.4	295.4	2602.0	1428.8	1987.1	1539.2	1471.7	750.9	191.9	279.1	128.7	157.3	472.8	608.4	985.3
20 Percent Slice		212.3	59.1	520.4	285.8	397.4	307.8	294.3	150.2	38.4	55.8	25.7	31.4	94.6	121.7	197.1
Suffolk	148.0	148.0														
Westchester	717.0	64.3	59.1	443.4					150.2							
Rockland	190.1			77.0	74.7					38.4						
Putnam	283.5				211.1	72.4										
Orange	1108.3	181.2				325.0	307.8	294.3								
Dutchess	1111.5	31.1	59.1	520.4	285.8	215.1										
Ulster	706.2					182.3	307.8	216.1								
Sullivan	262.9							78.2	150.2	34.5						
Columbia	257.6	212.3		45.3												
Greene	165.7		59.1	102.7						3.9						
Delaware	223.6			223.6												
Rensselaer	119.6											119.6				
Albany	38.1										38.1					
Schoharie	123.8			32.5	73.6						17.7					
Otsego	280.9							211.9	69.0							
Chenango	231.8					231.8										
Broome	561.1				40.5	397.4	123.2									
Saratoga	395.4	206.8							150.2	38.4						
Schenectady	19.0												19.0			
Montgomery	279.4						184.6	82.4					12.4			
Fulton	263.2	5.5	59.1	198.6												
Herkimer	273.2						173.8	99.4								
Oneida	64.6								64.6							
Madison	137.8				85.2	52.6										
Cortland	229.5							194.9	34.6							
Tioga	232.6			232.6												
Warren	247.0					113.0	134.0									
Hamilton	23.6								23.6							
Lewis	118.2							105.6	12.6							
Tompkins	385.3	212.2	59.0	48.3					27.4	38.4						
Cayuga	387.2				51.5	241.1								94.6		
Oswego	388.8								68.5	38.3				282.0		
Chemung	507.7			472.1	35.6											
Schuyler	83.7					83.7										
Seneca	175.4					72.7	102.7									
Ontario	394.2						205.3	188.9								
Wayne	397.0													96.2		

PLANNING AREA B -- NEW YORK STATE (Page 2 of 2)

		Kings	Nassau	Albany	Rensselaer	Schenectady	Monroe	Erie	Niagara	
Risk Population		2602.0	1428.8	279.1	128.7	157.3	608.4	985.3	160.9	
20 Percent Slice		520.4	285.8	55.8	25.7	31.4	121.7	197.1	32.2	
Host County	Capacity									
Jefferson NY	442.5			133.2		125.9				(Partially filled)
Yates NY	99.2			90.1	9.1					
Monroe NY	517.4						517.4			
Orleans NY	186.5						91.0			(Partially filled)
Genesee NY	293.6							131.3		(Partially filled)
Erie NY	641.0							641.0		
Niagara NY	373.9							213.0	160.9	
Wayne PA	116.3	116.3								
Susquehanna PA	171.7		171.7							
Bradford PA	289.8	89.2	200.6							
Tioga PA	198.5		198.5							

NOTE: The following New York counties were not used: Allegany, Cattaraugus, Chautauqua, Livingston, Steuben, and Wyoming.

PLANNING AREA C1 -- NORTHEAST NEW JERSEY

Host County	Capacity	Bergen NJ	Hudson NJ	Essex NJ	Passaic NJ	Union NJ	Middlesex NJ	Morris NJ	Somerset NJ	Sussex NJ	Hunterdon NJ	Warren NJ	Northampton PA	Lackawanna PA
Risk population		897.1	609.3	932.3	443.5	543.1	574.7	334.6	142.9	23.8	18.8	33.4	181.6	230.5
20 Percent Slice		179.4	121.9	186.5	88.7	108.6	114.9	66.9	28.6	4.8	3.8	6.7	36.3	46.1
Hunterdon NJ	254.6	7.1	20.2			108.6	114.9				3.8			
Somerset NJ	140.1	2.0	109.5						28.6					
Morris NJ	244.3	177.4						66.9						
Sussex NJ	268.6		12.4	186.5	64.9					4.8				
Warren NJ	202.8	172.3			23.8							6.7		
Pike PA	59.1		59.1											
Monroe PA	206.1		42.6	163.5										
Northampton PA	164.0												164.0	
Lehigh PA	136.4			23.0			113.4							
Carbon PA	252.9				88.7	108.6	1.5	54.1						
Lackawanna PA	18.0													18.0
Wyoming PA	18.5													18.5
Luzerne PA	198.5	113.7						12.8	28.6	4.8	3.8	6.7		28.1
Schuylkill PA	800.4	65.7	121.9	186.5	88.7	108.6	114.9	66.9	28.6	4.8	3.8	6.7		3.3
Columbia PA	275.6	179.4	96.2											
Sullivan PA	29.8			5.5										24.3
Montour PA	82.5		25.7	56.8										
Northumberland PA	496.0	179.5	23.1		69.9	108.6	114.9							
Snyder PA	146.3						77.0	67.0	2.3					
Union PA	143.0			124.2	18.8									
Lycoming PA	566.5		98.6	186.3	88.7	108.7	38.1							
Clinton PA	188.6							66.9	54.8	9.4	7.4	13.3		36.8
Centre PA	496.8												17.6	55.4 (Partially filled)

Potter, Cameron, Clearfield, and other northwestern Pennsylvania counties not used.

PLANNING AREA C2 -- PHILADELPHIA-NEW JERSEY

		Monmouth NJ	Ocean NJ	Atlantic NJ	Cumberland NJ	Burlington NJ	Mercer NJ	Camden NJ	Gloucester NJ	Salem NJ	Philadelphia PA	Bucks PA	Montgomery PA	Delaware PA	York PA	Dauphin PA	Franklin PA
Risk Population		418.0	32.6	47.5	34.1	316.2	304.0	434.5	140.2	42.0	1950.1	344.7	495.9	590.3	260.4	188.5	85.9
20 Percent Slice		83.6	6.5	9.5	6.8	63.2	60.8	86.9	28.0	8.4	390.0	68.9	99.2	118.1	52.1	37.7	17.2
Host County	Capacity																
Bucks	351.7	158.8				63.2	60.8					68.9					
Montgomery	640.3	8.4	11.5	9.5	6.8			86.9	28.0		390.0		99.2				
Chester	1352.0	83.6	8.0	19.0	13.6	126.4	60.8	173.8	56.0	16.8	557.8			236.2			
Berks	354.9						60.8				126.0	68.9	99.2				
Lancaster	208.4									8.4	96.2	68.9		34.9			
Lebanon	498.3	83.6	6.5	9.5	6.8	63.2	60.8	85.5					99.2	83.2			
York	41.1														41.1		
Dauphin	176.8															176.8	
Perry	129.1										16.3	68.9	43.9				
Cumberland	220.6										220.6						
Adams	185.3							1.4	28.0	8.4	136.5				11.0		
Franklin	74.7																74.7
Juniata	83.6												55.3	28.3			
Mifflin	226.3	83.6	6.6	9.5	6.9	29.9								89.8			
Huntingdon	195.5					33.5	60.8	86.9			14.3						
Fulton	53.9										1.8				52.1		
Blair	152.5										152.5						
Bedford	211.8								28.2	8.4	175.2						
Cambria	206.6													64.8	130.1	11.7	
Somerset	284.2										62.9	69.1	99.1	53.1			
Indiana	365.3														26.1		11.2

PLANNING AREA D -- BALTIMORE-WILMINGTON

		Kent DE	New Castle DE	Anne Arundel MD	Baltimore MD	Baltimore City MD	Harford MD	Howard MD	Kent MD	Frederick MD	Washington MD	Allegany MD
Risk Population		49.9	375.8	286.7	612.0	905.8	106.4	62.4	4.2	27.3	93.6	40.0
20 Percent Slice		10.0	75.2	57.3	122.4	181.2	21.3	12.5	0.8	5.5	18.7	8.0
Host County	Capacity											
Sussex DE	401.8	10.0	150.4	90.4		150.0						
Cecil MD	102.3		75.2				26.3		0.8			
Wicomico MD	271.2		75.2	57.3	52.1	86.6						
Worcester MD	122.2	39.9	21.4	57.5					3.4			
Somerset MD	94.6		53.6			41.0						
Carroll MD	136.5			57.3	79.2							
Frederick MD	288.4			24.2	43.2	181.2		12.5		27.3		
Washington MD	51.1										51.1	
Allegany MD	220.2				41.9	138.3						40.0
Garrett MD	107.4	(Partially filled)									42.5	
Berkeley WV	181.8				16.0	140.7	16.3	8.8				
Jefferson WV	106.4				106.4							
Morgan WV	42.7				8.9		21.3	12.5				
Frederick VA	144.5				122.6	9.5	8.7	3.7				
Winchester City	73.2				61.2	12.0						
Clarke VA	40.5					40.5						
Warren VA	76.5					76.5						
Shenandoah VA	114.3				80.5		33.8					
Page VA	82.9					28.5		24.9	(Partially filled)			

PLANNING AREA E1 -- WASHINGTON AREA

		District of Columbia	Mont-gomery MD	Prince Georges MD	Charles MD	St.Marys MD	Arlington VA	Fairfax VA	Alexandria City VA
Risk population		756.5	518.6	657.4	16.1	19.8	174.3	487.8	110.9
20 Percent Slice		151.3	103.7	131.5	3.2	4.0	34.9	97.6	22.2
Host County	Capacity								
Montgomery MD	21.3		21.3						
St. Marys MD	1.6					1.6			
Loudoun VA	101.8		101.8						
Prince William VA	406.6	151.3		131.5			34.9	66.7	22.2
Fauquier VA	93.0		86.5	6.5					
Stafford VA	98.3	69.6						28.7	
Rappahannock VA	26.0		1.8					24.2	
Culpeper VA	91.1			4.0			11.5	75.6	
Spottsylvania VA	82.1	9.5		72.6					
Fredericksburg	72.2	72.2							
King George VA	40.2			27.4	6.4	6.4			
Madison VA	43.2		43.2						
Orange VA	69.0	12.4	56.6						
Greene VA	26.2	26.2							
Louisa VA	70.0			70.0					
Caroline VA	69.6			24.0			23.4		22.2
Westmoreland VA	60.7	53.5			3.2	4.0			
Richmond VA	32.5	23.7		8.8					
Essex VA	35.5	35.5							
Albemarle VA	188.9			52.7			34.9	79.1	22.2
Charlottesville	194.4	72.2	103.7					18.5	
Rockingham VA	239.4			129.4			34.9	52.9	22.2
Harrisonburg	73.0		28.3					44.7	
Fluvanna VA	38.1	30.9			3.2	4.0			
Goochland VA	50.3	48.2		2.1					
Buckingham VA	53.0			53.0					
Nelson VA	58.5			0.6			34.7	1.1	22.1
Augusta VA	221.1	143.2		74.8					
Waynesboro	83.5	8.1	75.4						
Staunton	122.5			(Partially filled)				96.3	
Cumberland VA	30.9				3.3	3.8	(Partially filled)		

PLANNING AREA E2 -- NORFOLK AREA

		York VA	Hampton City VA	Newport News City VA	Williams-burg VA	Norfolk City VA	Portsmouth City VA	Virginia Beach City VA	Chesapeake City VA
Risk Population		33.2	120.8	138.2	9.1	308.1	111.0	172.1	89.6
20 Percent Slice		6.6	24.2	27.6	1.8	61.6	22.2	34.4	17.9
Host County	Capacity								
Isle of Wight	44.1		24.2	19.9					
James City Co.	14.9	5.4		7.7	1.8				
Gloucester	18.7	1.2	17.5						
Mathews	35.8	2.7	5.5	27.6					
Charles City Co.	13.2		1.9	7.7	3.6				
New Kent	26.5	1.2		23.5	1.8				
King William	37.5	8.1	5.2	24.2					
King and Queen	27.5	3.3		24.2					
Middlesex	31.5	3.9	24.2	3.4					
Lancaster	45.6	3.3	42.3						
Northumberland	46.2	4.1			1.9	(Partially filled)			
Accomack	86.7					86.7			
Northampton	72.2					37.8		34.4	
Nansemond	175.8					61.6	22.2	68.8	23.2
Suffolk City	49.3					14.5	22.2		12.6
Surry	29.4						29.4		
Southampton	92.9					36.5		34.4	22.0
Franklin City	34.4					34.4			
Sussex	57.3						15.0	28.5	13.8
Greensville	48.0					28.3	19.7		
Emporia City	26.5						2.5	6.0	18.0
Brunswick	80.9	(Partially filled)				8.3			

PLANNING AREA E3 -- SOUTHERN VIRGINIA

		Prince George County	Colonial Hts. City	Hopewell City	Petersburg City	Richmond City	Lynchburg City	Roanoke City and County	Salem City	Bristol City	
Risk Population		26.5	15.1	23.5	36.1	249.4	54.1	159.5	22.0	14.9	
20 Percent Slice		5.3	3.0	4.7	7.2	49.9	10.8	31.9	4.4	3.0	
Host County	Capacity										
Chesterfield	46.3	5.3	12.0	16.9	12.1						
Henrico	422.8					249.4					(Partially filled)
Dinwiddie	2.3				2.3						
Amelia	38.0				3.5						(Partially filled)
Nottoway	36.0	8.1	3.1	6.6	18.2						
Prince George	13.1	13.1									
Campbell	42.4						42.4				
Amherst	28.0						11.7				(Partially filled)
Botetourt	50.7							46.3	4.4		
Franklin	140.8							113.2			(Partially filled)
Montgomery	235.8								17.6		(Partially filled)
Washington	49.4									14.9	(Partially filled)

APPENDIX 3

TRANSPORTATION SUMMARIES

BOSTON AND ADJACENT RISK AREAS

The Area

The Boston risk area cannot be considered alone because other urbanized areas in the eastern part of New England use the same highway network and other transportation resources as the Bostonians. Hence, the area treated here comprises six counties in Massachusetts, four counties in New Hampshire, and four counties in Rhode Island, as listed in Table 1. These counties constitute subarea A1 in the allocation contained in Appendix 1, with the exception that the four western counties--New London, Connecticut; Windham, Connecticut; Worcester, Massachusetts; and Cheshire, New Hampshire--and all counties above the key cordon line have been omitted. The reason that the four western counties are not included in the analysis is that they have ample routes to the north that are unlikely to be used by the main body of relocatees from the area studied. To include them would distort the analysis.

The Relocation

The risk population totaling 5.1 million persons will be relocated to host areas in southern Rhode Island, central and southeastern Massachusetts, Vermont, New Hampshire, and Maine. An analysis of the allocation in Appendix 1 indicates that 3.2 million persons must travel north and northeast across the Massachusetts border to relocate in host areas within eastern New Hampshire and Maine. This portion of the relocation appears to pose the most difficult transportation problem in the area and is the focus of the analysis.

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THE FEASIBILITY OF CRISIS RELOCATION IN THE NORTHEAST CORRIDOR.(U)

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Table 1

BOSTON AND ADJACENT RISK AREAS

Automobile Relocation

(thousands)

Line	Item	Source	Massachusetts								New Hampshire					Rhode Island						
			Barnstable	Bristol	Essex	Middlesex	Norfolk	Plymouth	Suffolk	Total	Hillsboro	Merrimack	Rockingham	Strafford	Total	Bristol	Kent	Newport	Providence	Washington	Total	Grand Total
1	Population	NOI*	96.7	444.3	637.9	1398.4	604.9	333.3	735.2		223.9	80.9	139.0	70.4		45.9	142.4	94.2	581.5	85.7		
2	Risk population	SRI	19.2	444.3	554.3	1300.0	590.5	218.3	735.2	3861.8	188.6	5.6	93.1	32.7	320.0	45.9	142.4	91.8	581.5	52.4	914.0	5095.8
3	Occupied housing units	Col. 85	32.9	141.5	201.6	419.6	177.1	97.0	248.0		68.2	24.5	41.7	20.7		13.2	42.7	24.3	189.8	22.6		
4	Persons per occupied housing unit	Col. 86	2.9	3.1	3.1	3.3	3.4	3.4	2.9		3.2	3.3	3.3	3.4		3.4	3.3	3.8	3.0	3.7		
5	Percent of occupied housing units with one or more automobiles	Col. 101	91.3	79.7	81.4	83.2	88.6	89.0	55.3		83.1	87.3	91.2	86.5		89.6	92.5	89.0	80.4	92.0		
6	Risk population as a percent of the total population	Line 2 ÷ 1	19.9	100.0	86.9	93.0	97.6	65.5	100.0		84.2	6.9	67.0	46.4		100.0	100.0	97.5	100.0	61.1		
7	Occupied housing units at risk	Line 3x6	6.5	141.5	175.2	390.2	172.8	63.5	248.0		57.4	1.7	27.9	9.6		13.2	42.7	23.7	189.8	13.8		1607.5
8	Occupied housing units at risk w/autos ≠1 autos	Line 7x5	5.9	112.8	142.6	324.6	153.1	56.5	137.1	932.6	47.7	1.5	25.4	8.3	82.9	11.8	39.5	21.1	152.6	12.7	237.7	1253.2
9	Persons in risk occupied housing units w/autos	Line 8x4	17.1	349.7	442.1	1071.2	520.5	192.1	397.6	2990.3	152.6	5.0	83.8	28.2	269.6	40.1	130.4	80.2	457.8	47.0	755.5	4015.4
10	Persons without autos	Line 2-9	2.1	94.6	112.2	228.8	70.0	26.2	337.6	871.5	36.0	0.6	9.3	4.5	50.4	5.8	12.0	11.6	123.7	5.4	158.5	1080.4

Source: U.S. Department of Commerce, Bureau of the Census, County and City Data Book, 1972, Table 2.

* U.S. Department of Commerce, Bureau of the Census, Number of Inhabitants.

Automobiles and Highways

Table 1 shows that there are 1.3 million first automobiles in the area under study (Line 8). Persons per occupied dwelling unit range from 2.9 to 3.8 and average 3.2. The allocation of first automobiles between the relocation to the north and to other areas, together with the number dependent on other modes of transportation, is estimated to be:

Mode	Thousands of Persons North	Other Host Areas	Total
First automobile	2,487	1,529	4,016
Other modes	669	411	1,080
Total	3,156	1,940	5,096

Only 79 percent of the persons in the risk areas live in a household with an automobile. Based on this factor, about 2.5 million persons would move north by first automobile, given sufficient highway capacity. The other 0.67 million going north live in households without an automobile and must be accommodated by other transportation resources.

Although only a detailed traffic flow study could determine the feasibility of moving this number of automobiles over the highway network, the border between Massachusetts and New Hampshire has been chosen as an approximate cordon line since all traffic from the south must traverse it to reach the host counties. Table 2 shows the main highways that feed central and eastern New Hampshire and Maine. Taking into account a possible bottleneck at Manchester, it appears that the seven highways shown would be those utilized in the case of a crisis relocation from eastern Massachusetts and Rhode Island. At 3.2 average passengers per automobile, there is capacity for approximately 2.42 million persons over a three-day period on these routes. This is somewhat less than the 2.5 million estimated above. Extra capacity could be obtained by, for example,

Table 2

BOSTON AND ADJACENT RISK AREAS: HIGHWAY CAPACITY--AUTOMOBILES
(Three Days)

Highway	Host Area	Highway Description	Outbound Lanes	Highway Capacity (Thousands) Lane	Highway	Persons
I-95	Maine	Divided, limited access	2	90.0	180.0	576.0
1		Undivided	2	54.0	108.0	345.6
125	Eastern New Hampshire	Undivided	1	54.0	54.0	172.8
I-93	Central New Hampshire	Divided, limited access	2	90.0	180.0	576.0
28		Undivided	1	54.0	54.0	172.8
3 Alt 3	Central New Hampshire	Divided, limited access	2	90.0	180.0	576.0
		Total capacity	10		756.0	2,419.2

making all four lanes of I-95 one-way outbound, with the parallel US 1 serving for backhaul of emergency vehicles. This move, alone, would increase the capacity over the cordon by 576,000 persons.

The excess highway capacity generated in this manner could be used in various ways. For example, it would be possible to move over one-half million persons by second automobile (at 3.2 persons per vehicle). Such a solution would require an additional 166,000 automobiles. An analysis indicates that more than 1.1 million will be left behind in the risk areas. Drivers are likely to be available in sufficient numbers but assignments of drivers to vehicles would have to be planned and road capacity is barely adequate. While it seems unlikely that it would be practical to move all those in need of transportation by second automobiles, these data indicate that local planners have the option to use this resource to the extent desired or that does seem practical.

Buses and Trucks

Since one or more limited-access highways must be converted to one-way outbound to handle first automobiles, the excess capacity created could be used by buses and trucks. It is estimated that there are approximately the following numbers of buses and trucks available to relocate those needing transportation to the north:

Type of Vehicle	Number of Vehicles	Vehicle Capacity	Single-Trip Capacity
Large buses	1,321	40	52,840
Small buses	2,994	30	89,820
Tractor trucks	5,456	30	163,680
Other trucks	80,199	10	801,990
Total	89,970		1,108,330

Capacities are based on factors discussed in Section II of this report. It is indicated above that, as with automobiles, there are more than

enough vehicles to carry 669,000 carless relocatees to the north. If a mix of vehicle types were used, including as few small trucks as possible--about 40,000--the passengers would average 14 per vehicle. If the undivided highways were dedicated to buses and trucks, the three-day capacities would be:

Highway	Outbound Lanes	Three-Day Capacity Vehicles	Three-Day Capacity Persons
US 1	2	27,000	378,000
NH 125	1	13,500	189,000
NH 28	1	13,500	189,000
Total		54,000	756,000

Thus, road capacity would not be a limitation if automobiles were confined to the limited-access routes (one or more one-way) and it appears that planners can make use of this mode to the extent feasible and practical. If only buses and tractor trucks were used, vehicle capacities would be higher and planning would be less complex. But round trips would be necessary and about the same number of lanes needed.

Railroads

There is no rail passenger service north of Newburyport, Massachusetts, so that persons would have to transfer to other modes in order to reach the host counties. There is an extensive freight rail network in the New England area. If this mode were chosen to move persons without an automobile, a detailed study would be required in conjunction with railroad personnel. However, an approximate estimate of capacity can be made. The Providence area has a Penn Central line to Boston, where two Boston and Maine lines continue to the host areas. Given half-hour headways and a 20-hour day, 180,000 persons could be relocated on each line in a three-day period for a total of 360,000 for the two lines leaving Boston--about half of those requiring transportation north.

Airplanes

There are a number of commercial airports in the risk and host areas under study. Based on the factors outlined in Section II, it would appear that the risk area airports could effect the departure of over 300,000 persons over a three-day period but that host county airports could land only 126,000. There does not seem to be any reason why the Manchester-Concord airport at about the cordon line could not be used for landings rather than departures. If this were done, 162,000 relocatees could be flown into the host or borderline host areas (189,000 if standees are permitted). Although this represents a small fraction of those requiring transportation, it is believed that the factors used are conservative and this appears to be a mode worthy of more detailed study.

Recapitulation

Of the 3.156 million persons relocating to the north, 2.487 million could move by first automobile if one of the divided, limited-access highways were converted to four lanes outbound. The remaining 669,000 in households without an automobile could be relocated within the three-day period by a combination of buses, trucks, rail cars and aircraft. One method is shown here:

Buses and trucks on one lane outbound	232,000
Two freight lines	360,000
Airplanes	126,000
Total (more than needed)	718,000

Commuters

In contrast to the relocation, the most severe commuting problem appears to occur in the area south of Boston. Specifically, almost 150,000 commuters (75,000 per shift) would have to enter and leave Cape Cod each day. All of these commuters would have to use US 6 and MA 28

at the entrance to Barnstable County, which cross two bridges. US 6 is multilane, divided, and MA 28 is in part two-lane undivided. At five persons per vehicle, calculations indicate that about 14,500 persons per hour could cross the bridges in each direction. Thus, the commuting period at the bridges for each shift would be over five hours. Clearly, staggered working hours would be required.

Air commuter capacity from Hyannis airport would be too small to change the situation significantly. Nor would mixing buses with carpooling automobiles. One possibility would be to dedicate route 28 for buses only. The route could handle 125 large vehicles per hour, which at an average load of 43 persons would move 5,375 persons per hour--more than double the capacity provided by carpools. In this case, over 17,000 persons could move over the two bridges per hour. Full use of buses in lieu of automobiles would further reduce the commuting period per shift to about 3-1/2 hours, still considerably longer than normal in the metropolitan area. Careful coordination of working hours would be required among the different communities, such as Boston and Providence.

NEW YORK CITY RISK AREA

The Area

The New York City risk area includes the entire population in the five boroughs and Nassau County on Long Island. It also includes over 90 percent of the population of Suffolk County on Long Island and over 80 percent of the population of Westchester and Rockland Counties immediately north of New York City. The total risk population is 11.3 million persons.

The Relocation

All but 148,000 persons are expected to relocate to 37 host counties to the north and northwest of New York City. (The 148,000 reside in Suffolk County and will relocate within the county.) All host counties are in New York State, with the exception of four in northeastern Pennsylvania. The capacity of the host counties is often shared with risk populations from other urbanized areas in New York State.

As shown in Table 3, there is very low automobile ownership in four of the nine counties and the entire risk population has only 2.1 million automobiles at its disposal (or one automobile for every 5.5 persons). There are estimated to be 6.4 million people who live in housing units with one or more automobiles and 4.9 million who have none.

The northern boundaries of Rockland and Westchester Counties have been chosen as the cordon line because 10.3 million persons must pass beyond this point. (Approximately one million persons are to be hosted in Westchester and Rockland Counties, where an extensive road system exists.) Of the 10.3 million who must relocate beyond the cordon line, about 5.8 million will move in 1.9 million first automobiles.

Table 3

NEW YORK RISK AREA

Automobile Relocation
(thousands)

Line	Item	Source	Bronx	Kings	Nassau	N.Y.	Queens	Rich-mond	Rock-land	Suf-folk	Westches-ter	Total
1	Population	NOI*	1471.7	2602.0	1428.8*	1539.2	1987.2	295.4	229.9	1127.0*	894.4	
2	Risk population	SRI	1471.7	2602.0	1428.8	1539.2	1987.2	295.4	191.9	1061.4	750.9	11,328.4
3	Occupied housing units	Col. 85	497.2	876.1	401.1	687.3	690.1	86.2	60.4	295.6	282.6	
4	Persons per occupied housing unit	Col. 86	2.9	2.9	3.5	2.2	2.8	3.4	3.8	3.8	3.1	
5	Percent of occupied housing units with one or more automobiles	Col. 101	37.6	41.5	91.7	21.5	63.6	80.1	90.8	93.1	82.6	
6	Risk population as a percent of the total population	Line 2 ÷ 1	100.0	100.0	100.0	100.0	100.0	100.0	83.5	94.2	84.0	
7	Occupied housing units at risk	Line 3x6	497.2	876.1	401.1	687.3	690.1	86.2	50.4	278.5	237.4	
8	Occupied housing units at risk w/ autos = #1 autos	Line 7x5	186.9	363.6	367.8	147.8	438.9	69.0	45.8	259.3	196.1	2,075.2
9	Persons in risk occupied housing units w/auto	Line 8x4	542.0	1054.4	1287.3	325.2	1228.9	234.6	174.0	985.3	607.9	6,439.6
10	Persons without autos	Line 2–9	929.7	1547.6	141.5	1214.0	758.3	60.8	17.9	76.1	143.0	4,888.9

* Corrected Census number.

Source: U.S. Department of Commerce, Bureau of the Census, County and City Data Book, 1972, Table 2.
* U.S. Department of Commerce, Bureau of the Census, Number of Inhabitants.

Table 4 shows the major highways crossing the cordon. The number of lanes are assessed at the narrowest point between the Bronx and the cordon. It is assumed that the capacity of the Taconic State Parkway could be increased by preventing cross traffic on those sections that are not limited access, thus obtaining the capacity of a limited-access highway. Assuming normal two-way highway use, the three-day capacity of this system is about 3.5 million people, well short of the requirement. If, however, the four limited-access highways were made one-way outbound, the three-day capacity would be 6.25 million persons, an excess of capacity that would permit some lanes or undivided highways to be dedicated to busing those without automobiles.

Railroads

Since highway capacities are already strained, use of rail and air modes assumes great importance in the New York area. There is an extensive rail network in New York State but only two lines connect New York City with the northern host areas. These are Penn Central main lines to Albany and Schenectady, with lines from there to the north and west. Across the Hudson in New Jersey are two more rail lines that go to the New York host counties, a Penn Central line to Albany and an Erie Lackawanna to Binghamton, Elmira, and other cities to the west. Given the factors developed in Section II of this report, it is estimated that 180,000 persons could be relocated via each line in a three-day period, or 720,000 persons in all.

Aircraft

There are one small and two large commercial airports in the risk area but only five, relatively small, commercial airports in the host counties. In consequence, it is estimated that nearly one-half million persons could depart the risk area in a three-day period but only about 144,000 could be landed in the host areas in the same time span. If

Table 4

NEW YORK CITY RISK AREA: HIGHWAY CAPACITY--AUTOMOBILES
(Three Days)

Highway	Description	Lanes	Highway Capacity (Thousands) Lane	Highway	Persons
I-87, Bronx River and I-287	Divided, limited access	3	90	270	837.0
Palisades Interstate	Divided, limited access	2	90	180	558.0
9W	Undivided	1	54	54	167.4
Sawmill River and Taconic	Divided, limited access[1]	2	90	180	558.0
Sprain Brook and 9	Undivided	1	54	54	167.4
22 and 101	Undivided	1	54	54	167.4
Hutchinson River, I-95, and 684	Divided, limited access	3	90	270	837.0
17 and 208	Undivided	1	54	54	167.4
	Total capacity	14		1,116	3,459.6

[1] It is assumed that several uncontrolled access points on this route are blocked.

standees are allowed, this number could be increased to 216,000. As in the Boston case, it is clear that, unless other receiving airports can be used, the capacity of the risk-area airports cannot be realized. Airports in up-State risk areas, however, should not be overlooked. The Rochester, Syracuse, Utica/Rome, and Albany airports are all located in or near host counties for the New York City area. By their use, another 108,000 persons could be accommodated (162,000 with emergency loading).

Buses and Trucks

On the basis of these calculations, rail and air transportation can move at best about 1.1 million of the 4.4 million persons requiring transport. Most, therefore, must relocate via the highway system. Buses and trucks are available in the New York City area in large numbers. Assuming that the distribution of buses and trucks is proportional to population, and that half of the trucks are adaptable to passenger service, capacities are estimated to be:

Type of Vehicle	Number of Vehicles	Vehicle Capacity	Single-Trip Capacity
Large buses	6,259	40	250,360
Small buses	10,550	30	316,500
Tractor trucks	9,760	30	292,800
Small trucks	202,353	10	2,023,530
Total	228,922		2,883,190

Even if one could somehow mobilize all of these vehicles, their one-way capacity would be short of the requirement.

One alternative would be to use only buses and tractor trucks and to have these vehicles make round trips. Lanes would have to be reserved for both directions of travel. The average capacity of these larger vehicles is 32 passengers each. If the New York Thruway (I-87) were used for large vehicles, the three outbound lanes would accommodate 67,500 large

vehicles with 2,160,000 passengers in three days. The fleet of 27,000 vehicles would need to make about three round trips to move this number. Assuming that buses and large trucks deliver relocatees the average relocation distance, 153 miles, at a speed of 40 miles per hour, and with one-hour turnaround, a complete round trip would take six hours, or three per day per vehicle.

Recapitulation

The New York City risk population--11,328,000 people--cannot be relocated within a three-day period, using the transportation resources available. However, the task could conceivably be accomplished in approximately four days if all limited-access highways were made one-way outbound. The following example illustrates one way that relocation could be accomplished in a little less than four days:

First Three Days	People Across Cordon (millions)
First automobiles	5.840
Buses and large trucks, one lane	0.720
Trains, four lines	0.720
Aircraft, all airports	0.25
	7.53
Fourth Day	
Buses and large trucks, 3 round trips	2.58
Trains, four lines	0.24
Aircraft, all airports	0.08
Total	10.43
Requirement	10.3

Commuters

Eight percent of the risk population, or 906,300 persons, are estimated to be commuters. Of these, 771,600 may have to commute between the New York City risk area and the counties of Westchester, Rockland, Orange and

Putnam to the north. (Commuters in Suffolk, Westchester, and Rockland commute within their own county only.)

A possible bottleneck could be the entrance to hosting areas of Rockland and Westchester Counties, approximated by I-287. There are a number of highways that cross this cordon, as shown below (listed from west to east):

State	Highway	Type	Outbound Lanes	Autos/per Hour	Persons/per Hour
New Jersey	Garden State Parkway to New York State Thruway	Divided, limited access	3	4,500	22,500
	Palisades Interstate Parkway	Divided, limited access	2	3,000	15,000
	9W	Undivided	1	500	2,500
New York	9	Undivided	1	500	2,500
	Sawmill River Parkway	Divided, limited access	2	3,000	15,000
	100	Undivided	1	500	2,500
	Bronx River/ Sprain Brook Parkway to Taconic State Parkway	Divided, limited access	2	3,000	15,000
	22	Undivided	1	500	2,500
	Hutchinson River Parkway to I-684	Divided, limited access	2	3,000	15,000
					92,500

As the tabulation indicates, even with this extensive highway network, an all-automobile mode would require over 8-1/3 hours, or over 4 hours for each of two shifts. As in other large areas, it is considered advisable to use some of the highways in an all-bus mode. There are an estimated 1,380 buses. If they were used on undivided highways for round trips, capacity would be doubled from 2,500 persons per hour per lane to 5,375 persons per hour (at an average of 43 persons per vehicle). With an average commuting distance of 50 miles, a round trip would approximate three hours, so that there appear to be enough buses to utilize three or four undivided highways in this manner. This would increase the total capacity by at least 8,625 and reduce the commute time to less than eight hours. There do not appear to be enough buses available to the New York City area commuters to take advantage of the divided, limited access highways. However, more detailed analysis plus planning could prove otherwise.

The commuting problems for New York City could be eased somewhat by continuing to operate the commuter rail lines which run from mid-Manhattan north to the essential workers' host areas. It is probably also worth considering use of the five subway lines that terminate in the Bronx, although commuters using both automobiles and commuter or subway trains will probably experience considerable congestion and difficulty in parking at the transfer points. These problems should be addressed in the detailed planning stage.

PHILADELPHIA RISK AREA

The Area

The Philadelphia-Southern New Jersey area analyzed here includes all or part of the population of nine counties in New Jersey and three in Pennsylvania representing the urbanized area of Philadelphia. These counties are listed in Table 5, together with data needed for the analysis. The area encompasses 4.7 million people that may be relocated in the event of a major crisis. This risk population, according to the final allocation, would be relocated westward into the State of Pennsylvania, using the transportation resources that are available.

Automobiles and Highways

It is estimated that 3.5 million of the 4.7 million persons at risk would have a first automobile available. At the average of 3.2 persons per automobile, approximately 1.1 million automobiles could be used, given sufficient highway capacity.

The western cordon that must be crossed by the relocatees is that formed by the western boundaries of Bucks, Philadelphia, and Delaware Counties. This cordon is roughly approximated by US highway 202. Although this highway cuts Bucks County in two, the heavily populated region is to the east of the highway. Highways crossing this cordon to the west are shown in Table 6, together with their estimated capacities. It appears from this table that unless some highways are converted to one-way outbound, the 3.5 million persons in first automobiles would require more than three days for the exodus. (Detailed analysis by highway officials might uncover additional routes.) If, however, the Pennsylvania Turnpike (I-276/I-76) were converted to one-way outbound,

Table 5

SOUTHERN NEW JERSEY/SOUTHEASTERN PENNSYLVANIA RISK AREA

Automobile Relocation

(thousands)

Line	Item	Source	New Jersey										Pennsylvania				
			Atlantic	Burling-ton	Camden	Cumber-land	Gloucester	Mercer	Monmouth	Ocean	Salem	Total	Bucks	Delaware	Phila-delphia	Total	Grand Total
1	Population	NOI*	175.0	323.1	456.3	121.4	172.7	304.0	461.8	208.5	60.3		415.1	601.4	1950.1		
2	Risk population	SRI	47.5	316.2	434.5	34.1	140.2	304.0	418.0	32.6	42.0	1769.1	344.7	590.3	1950.1	2885.1	4654.2
3	Occupied housing units	Col. 85	60.7	84.8	138.4	37.1	49.7	93.5	135.2	68.4	18.7		117.6	180.7	642.1		
4	Persons per occupied housing unit	Col. 86	2.8	3.8	3.2	3.2	3.4	3.2	3.3	3.0	3.2		3.5	3.3	3.0		
5	Percent of occupied housing units with one or more automobiles	Col. 101	72.4	92.9	83.7	85.1	90.9	82.6	88.6	89.8	89.0		94.4	86.1	60.3		
6	Risk population as a percent of the total population	Line 2 ÷ 1	27.1	97.9	95.2	28.1	81.2	100.0	90.5	15.6	69.7		83.0	98.2	100.0		
7	Occupied housing units at risk	Line 3x6	16.4	83.0	131.8	10.4	40.4	93.5	122.4	10.7	13.0		97.6	177.4	642.1		
8	Occupied housing units at risk w/autos = #1 autos	Line 7x5	11.9	77.1	110.3	8.9	36.7	77.2	108.4	9.6	11.6		92.1	152.7	387.2		1083.7
9	Persons in risk occupied housing units w/autos	Line 8x4	33.3	293.0	353.0	28.5	124.8	247.0	357.7	28.8	37.1		322.4	503.9	1161.6		3491.1
10	Persons without autos	Line 2-9	14.2	23.2	81.5	5.6	15.4	57.0	60.3	3.8	4.9		22.3	86.4	788.5		1163.1

Source: U.S. Department of Commerce, Bureau of the Census, County and City Data Book, 1972, Table 2.

* U.S. Department of Commerce, Bureau of the Census, Number of Inhabitants.

Table 6

PHILADELPHIA RISK AREA: HIGHWAY CAPACITY--AUTOMOBILES
(Three Days)

Highway	Description	Lanes	Highway Capacity (Thousands) Lane	Highway	Persons
1	Divided	2	72	144	461
3	Divided	2	72	144	461
30	Divided	2	72	144	461
76	Divided, limited access[1]	1[1]	54[1]	54	173
276/76	Divided, limited access	2	90	180	576
422	Undivided	2	54	108	346
73	Undivided	1	54	54	173
322/202	Undivided	1	54	54	173
	Total capacity	13		882	2,824

[1] Highway 76 can only be fed into Highway 23, a two-lane highway. (Pennsylvania Turnpike is already counted full to capacity.)

all but about 21,000 first automobiles could be accommodated in a three-day period. If US 30 and/or US 1 were also converted, there would be some excess capacity for busing those without autos. There are about 1.2 million persons without access to an automobile. Since highway capacities are strained, use of rail and air travel will be explored first.

Railroads

There is commuter, passenger, and freight rail service from Philadelphia into the Pennsylvania host counties. The main lines are the Reading to Harrisburg, the Penn Central to Lancaster, Harrisburg, and Altoona, and a line through Chester County into Maryland. Using the factors developed in Section II of this report, 540,000 persons could be relocated by train in a three-day period. As Philadelphia is so well served by commuter and passenger trains, it appears that there would be less need for freight cars than in other areas studied.

Aircraft

The only commercial airport serving the host area is that at Harrisburg-York. This airport does not serve planes larger than the DC-9 and B-707 and appears incapable of receiving as many as 100,000 persons in a three-day period. Thus, aircraft are a minimal resource in this area.

Buses and Trucks

Assuming that buses and trucks are distributed proportional to the population and that half the trucks are suitable for passenger use, the following are estimated to be available in the risk area to move relocatees:

Type of Vehicle	Number of Vehicles New Jersey	Number of Vehicles Pennsylvania	Number of Vehicles Total	Number of Persons Vehicle Capacity	Number of Persons Single-Trip Capacity
Large buses	907	1,587	2,494	40	99,760
Small buses	2,427	3,756	6,183	30	185,490
Tractor trucks	5,060	8,132	13,192	30	395,760
Other trucks	55,779	102,919	158,698	10	1,586,980
					2,267,990

If half of those requiring transportation use rail and air modes, the remainder could be moved by one trip of the buses and tractor trucks. One lane of US 1 or US 30 dedicated to buses and trucks would provide sufficient capacity.

Recapitulation

Philadelphia-South New Jersey has only one limited-access highway going to the host counties to the west. Even if railroads and one airport were used to capacity, it appears that both the Pennsylvania Turnpike and one divided highway must be made one-way outbound to accommodate first automobiles and buses and trucks, if the movement is to be completed in three days.

Commuters

The 400,000 commuters to Philadelphia and South New Jersey will use the highways discussed above as there is no host capacity in southern New Jersey. At five persons per automobile, the eight highways would allow all commuters to pass over a period of less than six hours. The commuting period for a single shift would extend over almost three hours, somewhat longer than normal for the area. Although automobiles could do the job, the use of buses may be preferable to increase the capacity and reduce the problem of staggered working hours.

BALTIMORE/WILMINGTON AND ADJACENT RISK AREAS

The Area

The Baltimore/Wilmington risk area includes seven contiguous counties and Baltimore City. These are listed in Table 7, together with their risk population and the percent of occupied housing units with at least one automobile. As the table shows, there is high automobile ownership in all the counties. Baltimore City, which comprises 38 percent of the risk population, is an area of low automobile ownership; more than 40 percent of the occupied housing units do not have an automobile.

The Relocation

For the most part, the relocation will be west and south out of the heart of the risk area of Baltimore/Wilmington. The movement west of Baltimore will encompass about 1.4 million persons. This will include 75 to 80 percent of Baltimore City, Baltimore County, and Harford County as well as 100 percent of Howard County and 8 percent of Anne Arundel County. Their host areas are in western Maryland, the panhandle of West Virginia, and seven counties in northwestern Virginia. Movement across the Chesapeake Bay and into southern Maryland and Delaware will consist of one-half million persons from Baltimore City, Baltimore County, and Anne Arundel County. Other persons moving south are approximately 350,000 from the Wilmington area, which includes Kent County, Delaware; Kent County, Maryland; and New Castle County, Delaware. Another 150,000 persons have relatively small distances to go and are not in the mainstreams of traffic.

Table 7

BALTIMORE/WILMINGTON RISK AREA

Automobile Relocation
(thousands)

			Delaware			Maryland							
Line	Item	Source	Kent	New Castle	Total	Anne Arundel	Baltimore	Baltimore City	Harford	Howard	Kent	Total	Grand Total
1	Population	Col. 3	81.9	385.9	467.8	297.5	621.9	905.8	115.4	62.4	16.1		
2	Risk Population	SRI	49.9	375.8	425.7	286.7	612.0	905.8	106.4	62.4	4.2	1,977.5	2,403.2
3	Occupied housing units	Col. 85	23.4	115.8		81.1	184.8	289.0	32.0	16.9	5.1		
4	Persons per occupied housing unit	Col. 86	3.5	3.3		3.6	3.3	3.1	3.6	3.6	3.1		
5	Percent of occupied housing units with one or more automobiles	Col. 101	90.4	86.6		91.9	92.1	58.9	91.5	94.4	83.1		
6	Risk population as a percent of the total population	Line 2 ÷1	60.9	97.3		96.4	98.4	100.0	92.2	100.0	26.1		
7	Occupied housing units at risk	Line 3x6	14.3	112.7		78.2	181.8	289.0	29.5	16.9	1.3		
8	Occupied housing units at risk w/autos = #1 autos	Line 7x5	12.9	97.6		71.9	167.4	170.2	27.0	16.0	1.1		564.1
9	Persons in risk occupied housing units w/autos	Line 8x4	45.2	322.1		258.8	552.4	527.6	97.2	57.6	3.4		1,864.3
10	Persons without autos	Line 2-9	4.7	53.7		27.9	59.6	378.2	9.2	4.8	0.8		538.9

Source: U.S. Department of Commerce, Bureau of the Census, County and City Data Book, 1972, Table 2.

These numbers are summarized below:

	(000)	
West of Baltimore	1,353.8	
East of Baltimore, across Chesapeake Bay	535.9	889.8
South from Wilmington area	353.9	
Other	159.6	
Total	2,403.2	

The 1.4 million persons traveling west of Baltimore represent the relatively more difficult relocation problem from the Baltimore/Wilmington area.

It is estimated that first automobiles will be used by almost 75 percent of the population relocating to the west. Thus, about 1 million persons relocating to the west live in occupied housing units with an automobile and could move by that mode, given sufficient highway capacity.

There are three highways out of Baltimore leading into the western host counties (see Table 8). As this table indicates, these highways could carry almost 1.3 million people--more than enough capacity to move those persons with a first automobile.

Second automobiles are in ample supply and could be used to some extent, but highway capacity is not sufficient to transport all persons by this mode. It appears that the use of buses and trucks, with their greater capacity, would be preferable.

As is true of the other areas analyzed, there are sufficient buses and trucks available in the Baltimore-Wilmington area to move persons without an automobile. If Highway 26 were used solely for this mode, 13,500 vehicles could travel outbound in the three days. Assuming an average of 20 persons per vehicle, 270,000 persons could relocate by this highway.

Table 8

BALTIMORE/WILMINGTON RISK AREA: HIGHWAY CAPACITY--AUTOMOBILES
(Three Days)

Highway	Description	Outbound Lanes	Highway Capacity (Thousands) Lane	Highway	Persons
West					
I-70	Divided, limited access	2	90.0	180.0	576.0
26	Two lanes, undivided	1	54.0	54.0	172.8
140+30	Four lanes, undivided	2	54.0	162.0	518.4
				396.0	1,267.2
South					
50	Divided	2	72.0	144.0	460.8
313	Two lanes, undivided	1	54.0	54.0	172.8
13	Divided	2	72.0	144.0	460.8
113	Two lanes, undivided	1	54.0	54.0	172.8
	Total capacity			396.0	1,267.2

There are two major freight lines that feed the western host areas from Baltimore. Using the factors developed in Section II, 360,000 persons could be relocated by this mode.

To Southern Host Areas

As indicated above, there would be approximately 890,000 persons traveling into the southern counties of Maryland and Delaware. The severest highway constraint is likely to occur at the northern border of Sussex County, as all the risk area population traveling south must cross this border before beginning to disperse in the host counties. However, as Table 2 shows, the north/south highways at this line all together have a carrying capacity of almost 1.3 million persons. Thus, it appears that all 890,000 persons could relocate by automobile, if this were desired. Again, for reasons previously expressed, it is probably preferable to use other modes, rather than second automobiles.

If Highways 313 or 113 were used for outgoing bus and truck traffic, at an average of 20 persons per vehicle, 270,000 persons could be relocated by this mode--30 percent of the population to be moved across this cordon. (Both of these highways could be used for outgoing buses and trucks, but it would require using all small trucks for the balance and is therefore not recommended.) If only buses and tractor-trucks and trailers were used, round trips would be required, reducing the outbound capacity to 7,500 vehicles per lane in the three-day period. Assuming an average of 30 persons per vehicle, these two highways could carry 450,000 persons--50 percent of the population to be moved across the cordon.

There is one major railroad freight line that feeds the southern host counties from Wilmington. There is no passenger line. Using the factors developed in the first section, 180,000 persons could be relocated to the southern host counties in the three-day period.

The risk/host area contains only two commercial airports: one at Baltimore and one at Wilmington. Both airports are in risk counties and about 100 miles from the nearest host counties to the south. Thus, unless noncommercial airports or alternate hosting areas are utilized, commercial aircraft cannot be used for relocation.

Summary Recapitulation

There appears to be sufficient highway capacity to move persons by first automobile, buses and trucks, although the relocation to western host counties is more constrained than that going to southern host counties. The use of the two railroad lines to the west could reduce this congestion and more than cover the requirements for the persons to be relocated. The relocation to the southern host counties of Maryland and Delaware can be accomplished without using the freight line, if desired. There are no commercial airports in host areas; therefore, aircraft are not included as a relocation mode.

Commuters

Almost all of the commuters will be relocated into the southern host counties of Maryland and Delaware, as shown below:

	(000)	
West of Baltimore	33.1	
East of Baltimore, across Chesapeake Bay	116.2	375.8
South from Wilmington area	34.1	
Other	8.8	
Total	192.2	

Because the majority of the commuters must cross the twin Chesapeake Bay Bridges before feeding into the four highways leading to the southern host counties, this bridge is considered the possible bottleneck.

The capacity of the bridge is assumed to be the same as a four-lane divided highway. A four-lane divided highway accommodates 12,000 persons per hour for each two lanes, using the factor of 5 persons per automobile. Thus, the 116,200 commuters would require almost 10 hours of the day to cross the bridge one way, five hours per shift. As is true of the other areas studied, staggered working hours would be required. Some buses could be used to mix in with the automobile traffic to increase the capacity slightly. As far as an all-bus mode is concerned, unless buses were "borrowed" from those available to other commuters, it appears there would not be enough available for this commute, even if the buses were able to make three round trips per day. In any event, the commuting must be worked out very carefully.

WASHINGTON D.C. RISK AREA

The Area

The Washington D.C. risk area contains 2.791 million persons residing within 14 jurisdictions: the District of Columbia, four counties in Maryland, and six counties and three cities in Virginia. About 50,000 persons within four of the counties in Virginia--Fauquier, Loudoun, Prince William, and Stafford--relocate within their county only, and the balance of 2.741 million people are those considered in this analysis (see Table 9).

The Relocation

There are 26 host counties and 5 independent host cities for the Washington D.C. risk area. They are located south and west of Washington: 6 of them lie west of the Blue Ridge mountains, with highway passes rising to about 4,000 feet. The average distance to host counties is 89 miles; the maximum distance is 158 miles.

Automobiles and Highways

As the table shows, if each occupied housing unit with at least one automobile in the risk area uses the "first automobile" for relocation, 702,600 automobiles would be put into service. (Line 8) First automobiles would carry about 2.220 million persons at an average of 3.2 persons per automobile, given adequate highway capacity.

Major highways to the south are Highway 5 and 301 in Maryland and Interstate 95 and Highway 1 in Virginia. These roads have capacities larger than that required to move relocatees from Washington to its southern host counties. Major highways to the west are 7, US 50, 211, and I-66

Table 9

WASHINGTON D.C. RISK AREA

Automobile Relocation
(thousands)

Line	Item	Source	D.C.	Maryland				Virginia Counties						Virginia Cities					
				Charles	Montgomery	Prince Georges	St. Marys	Arlington	Fairfax	Fauquier	Loudoun	Prince Wm.	Stafford	Alexandria	Fairfax	Falls Church	Totals	Four Counties*	Balance
1	Population	NOI*	756.5	47.7	522.8	661.2	47.4	174.3	455.0	26.4	37.2	111.1	24.6	110.9	22.0	10.8	3,007.9		
2	Risk population	SRI	756.5	16.1	518.6	657.4	19.8	174.3	455.0	6.5*	14.0*	24.8*	4.1*	110.9	22.0	10.8	2,790.8	49.4	2,741.4
3	Occupied housing units	Col. 85	262.5	12.1	156.7	193.0	12.1	69.4	126.5	7.6	10.4	27.7	6.7	42.5	6.1	3.7			
4	Persons per occupied housing unit	Col. 86	2.8	3.9	3.3	3.4	3.9	2.5	3.5	3.4	3.5	4.0	3.6	2.6	3.5	2.9			
5	Percent of occupied housing units with one or more automobiles	Col. 101	55.8	89.9	93.5	92.1	90.4	85.7	96.2	84.7	88.7	95.1	89.2	83.3	97.6	92.5			
6	Risk population as a percent of the total population	Line 2 ÷ 1	100.0	33.7	99.2	99.4	41.7	100.0	100.0	24.6	37.6	22.3	16.6	100.0	100.0	100.0			
7	Occupied housing units at risk	Line 3x6	262.5	4.1	155.4	191.8	5.0	69.4	126.5	1.9	3.9	6.2	1.1	42.5	6.1	3.7			
8	Occupied housing units at risk w/autos = #1 autos	Line 7x5	146.5	3.7	145.3	176.6	4.5	59.5	121.7	1.6	3.5	5.9	1.0	35.4	6.0	3.4	714.6	12.0	702.6
9	Persons in risk occupied housing units w/auto	Line 8x4	410.2	14.4	479.5	600.4	17.6	148.8	426.0	5.4	12.2	23.6	3.6	92.0	21.0	9.9	2,264.6	44.8	2,219.8
10	Persons without autos	Line 2-9	346.3	1.7	39.4	57.0	2.2	25.5	29.0	*	*	*	*	18.9	1.0	0.9			521.9

* Move within the county only

Source: U.S. Department of Commerce, Bureau of the Census, County and City Data Book, 1972, Table 2.
* U.S. Department of Commerce, Bureau of the Census, Number of Inhabitants.

combined with 55. Three of these four highways narrow to two lanes shortly after they enter the host territory. Only Route 211 continues with two outbound lanes available past the first two host counties on its route. The host counties to the west and southwest that are fed by these highways have a capacity of 1.698 million persons: these four roads will carry only 0.979 million. If Maryland Route 5, together with 301, I-95 south, and Highway 1, is also utilized for the relocation to the western host counties, it appears that a total of 2.189 million persons could be relocated to the host counties by auto (see Table 10). For some, this would entail driving as far south as Richmond and then west into the host counties via I-64 and its connecting roads. This is only slightly less than 2.220 million that have first automobiles available to them. About an hour would be required to move the remainder.

If only those persons that live in housing units with an automobile were relocated via first autos, about one-half million people would remain to be relocated by secondary modes. Although there are more than enough second autos to relocate these people, this is not considered to be an efficient use of the limited capacity. Other modes are discussed below.

Buses and Trucks

The number of buses and trucks available to the Washington D.C. risk area population is estimated on the basis of the ratio of the risk population to the population of the state and applying that factor to the number of buses and trucks in the state. This procedure yields the following estimates:

	D.C.	Maryland	Virginia	Total
Large buses	1,585	559	324	2,468
Small buses	747	2,553	1,481	4,781
Tractor trucks	472	4,301	2,871	7,644
Other trucks	17,283	92,781	83,306	193,370

Table 10

WASHINGTON, D.C. RISK AREA: HIGHWAY CAPACITY--AUTOMOBILES
(Three Days)

Highway	Description	Outbound Lanes	Highway Capacity (Thousands) Lane	Highway	Persons
South					
5 and 301	Divided	2	72.0	144.0	460.8
1	Undivided	1	54.0	54.0	172.8
I-95	Divided, limited access	2	90.0	180.0	576.0
West					
211	Divided	2	72.0	144.0	460.8
7	Undivided	1	54.0	54.0	172.8
50	Undivided	1	54.0	54.0	172.8
I-66	Divided, limited access	1	54.0	54.0	172.8
55	Undivided				
	Total capacity			684.0	2,188.8

Carrying capacity is estimated below, taking into account the assumption that only half of the trucks would be suitable for relocating people.

Large buses	2,468	@ 40	98,720
Small buses	4,781	@ 30	143,430
Tractor trucks	3,822	@ 30	114,660
Other trucks	96,685	@ 10	966,850

This listing illustrates the fact that there are ample buses and trucks available in the area to move the half-million people that do not have an automobile, if there were sufficient highway capacity (or additional time). If buses and trucks are to be used, additional capacity could be obtained by converting the normal inbound lanes of some highways to outbound lanes. For example, if I-95 were converted to four lanes outbound and one lane of Highway 1 (which parallels I-95) used for emergency backhaul, the two extra lanes would accommodate 22,500 large vehicles in the three-day period. By using all the buses and tractor trucks that appear to be available for relocation and as few small trucks as possible--11,430--the average persons per vehicle would be 21. In this manner, 472,500 additional persons could be moved over the network in the three-day period.

There are other alternatives, of course. All four lanes of I-95 could be used for automobiles only and, for example, one of the undivided, two-lane highways could be devoted solely to buses and trucks. Estimated vehicle trips would be 13,500 outbound in the three days. The stock of buses and tractor trucks would be used first, plus about 2,400 other trucks. This route, with this mix of vehicles, would carry about 378,000 relocatees in the three-day period. (If it were determined to use only large buses and to have them make round trips, only 300,000 persons would be accommodated, due to the reduced capacity of outbound traffic.)

Railroads

There is one railroad line that serves the southwest host area for Washington. The James Whitcomb Riley Amtrak (Southern Railway) line extends from Washington to Charlottesville, Staunton and Clifton Forge. If present regulations were followed, each passenger train could carry no more than 18 cars: 17 coaches and 1 baggage car. By filling the cars to 1-1/2 times their normal capacity, a train could carry 1,500 passengers in one run. The time to Charlottesville is 2 hours and 15 minutes. Given one hour turnaround time at each end, the complete cycle would take 6-1/2 hours. On this basis, the train could make about three round trips per 20-hour day, or nine in the three-day period. Passengers carried would total 4,500 in one day or 13,500 in three days.

Freight cars also run on this line and could be used to relocate persons from the Washington area. Thirty freight cars could carry the same number of passengers per train as the passenger train--1,500. Given half-hour headways and a 20-hour day, 60,000 persons could be routed to Charlottesville for a total of 180,000 in three days. As the host capacity of Charlottesville is over 190,000 persons, it is assumed that the relocatees would require relatively short bus or truck rides to their destinations.

Airplanes

Washington National Airport is a convenient location for many of the risk area residents, and it has a large capacity. In the 12 months ending 30 June 1975 the airport handled 155,000 departing aircraft, for an average of 425 per day. As the airport is closed to jets for eight hours every evening and does not run at full capacity in the other hours, a conservative departure is assumed to be 750 departures per day if there were a crisis relocation. If each aircraft carried an average of 125 passengers, 281,000 passengers could be relocated in three days, assuming a 250 mile journey and 2-1/3 hour round-trip developed in an

illustration in the first section of this report. The operation would require about 90 to 100 aircraft depending on the models employed.

Within the host area there are only three commercial airports, and these are all relatively small--Charlottesville, Albemarle County; Staunton, Augusta County; and Hot Springs in Bath County. These airports could receive 100,000 relocatees at most. Airports in other host areas would be needed to take full advantage of the capacity at Washington National Airport.

Recapitulation

There are about 2.740 million people to be relocated to counties other than their own. Given the assumptions developed in Section II, unless at least some normal inbound lanes are converted to outbound, the relocation could not be completed in three days.

One method of completing the relocation in three days is shown below:

	(000s)
First automobile	2,188.8
Buses and trucks outbound on two otherwise inbound lanes of I-95	472.5
Railroads	80.1
Total	2,741.4

Commuters

About 223,000 people in the urbanized area are considered to be essential workers. Of these, some 210,400 must commute from nearby counties.

The tabulation below shows the distribution of **commuters:**

		District of Columbia	Montgomery Maryland	Prince George, Md.	Charles Maryland	St. Marys Maryland	Arlington Virginia	Fairfax* Virginia	Alexandria City, Va.
Commuter Population	219.5	60.5	41.5	52.6	1.3	1.6	14.0	39.1	8.9
Host county	**Total**								
Montgomery MD	**8.5**		**8.5**						
St. Marys MD	**0.6**					0.6			
Loudoun VA	**33.0**		**33.0**						
Prince William VA	**162.7**	**60.5**		**52.6**			**14.0**	**26.7**	**8.9**
Stafford VA	**11.5**							**11.5**	
Rappahannock VA	**0.9**							**0.9**	
King George VA	**2.3**				**1.3**	1.0			

* **Including Fairfax City and Falls Church**

Almost three-quarters of the commuters will be traveling north and south between the District of Columbia and its suburbs to Prince William County in Virginia. Fortunately, there is an excellent highway system serving this area. The Beltway around the District can feed commuters from the city and its suburbs into the following highways serving Prince William:

	Lanes each Direction	Autos per hr each Direction	Persons per hr each Direction
I-66 Divided, limited access	2	3,000	15,000
I-95 Divided, limited access	2	3,000	15,000
1 Undivided	1	500	2,500
50 to 29 & 211 Divided	2	2,400	12,000
			44,500

At five persons per vehicle, 44,500 persons could travel each way in one hour. Thus, the 162,700 commuters to Prince William require only a little over 3-1/2 hours. Although this is a relatively simple commute situation, the six communities would be well advised to coordinate their shifts to avoid overloads at any one time. At the same time, planners may prefer to use buses on some of the highways to increase the capacity and decrease the possibility of overloads.

The 33,000 commuters between Montgomery County and Loudoun County could use Highways 7, 28, and 270. Only 7 entering Loudoun County is divided. These highways could accommodate about 2,200 automobiles in one direction per hour, or about 11,000 persons per hour. Only about three hours of the day would be required here for entry or exit, using this mode.

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The feasibility of relocation of 47 million persons over a three-day period from areas at potential risk in event of nuclear attack in the densely-populated Northeast and Middle Atlantic regions was examined to determine whether travel distances to host areas were reasonable, transportation capacities were sufficient, and whether fallout protection could be provided. It was found that congregate-care housing at 20 square feet per person could be provided at an average travel distance of 100 miles. Transportation constraints in the vicinity of the very large cities would require that limited-access highways be made one-way outbound. New York City was identified for special study. High-quality fallout protection (expedient shelter construction) would be required in much of the study area.

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